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Business Case Analysis of Medium Altitude Global ISR Communications (MAGIC) UAV System

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BUSINESS CASE ANALYSIS OF MEDIUM ALTITUDE GLOBAL ISR COMMUNICATIONS (MAGIC) UAV SYSTEM

by

Ramesh Kolar

June 2012

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This study is a business case analysis of a Medium Altitude Global ISR Communication (MAGIC) UAV system. The MAGIC platform is analyzed together with three other medium-altitude ISR platforms. A cost model for RDT&E and O & S for the MAGIC is developed based on historical data. A baseline case for MAGIC is then developed with Average Production Unit Cost (APUC) of $17M, RDT&E cost of $510M, and discount factor of 0.025 for the analysis. A Net Present Value of Life Cycle Cost (NPVLCC) and a return ratio as defined by the ratio of the NPVLCC of alternative platforms to the NPVLCC of MAGIC are used in the analysis.

Results are presented for 500, 1000, 2000, and 3000 nm ranges. MAGIC outperforms Reaper and Global Hawk, while Predator outperforms MAGIC at the 500 nm. MAGIC outperforms all others in the 1000, 2000 and 3000 nm range. The analysis is extended to cover other payloads for the same ranges. The results show that MAGIC is favored over Reaper for 1000 nm and 2000 nm range, and the return ratio is marginal for 500 nm. MAGIC is favored in all ranges when compared with Global Hawk.

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BUSINESS CASE ANALYSIS OF MEDIUM ALTITUDE GLOBAL ISR COMMUNICATIONS (MAGIC) UAV SYSTEM

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Submitted in partial fulfillment of the
requirements for the degree of

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BUSINESS CASE ANALYSIS OF MEDIUM ALTITUDE GLOBAL ISR COMMUNICATIONS (MAGIC) UAV SYSTEM

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Results are presented for 500, 1000, 2000, and 3000 nm ranges. MAGIC outperforms Reaper and Global Hawk, while Predator outperforms MAGIC at the 500 nm. MAGIC outperforms all others in the 1000, 2000 and 3000 nm range. The analysis is extended to cover other payloads for the same ranges. The results show that MAGIC is favored over Reaper for 1000 nm and 2000 nm range, and the return ratio is marginal for 500 nm. MAGIC is favored in all ranges when compared with Global Hawk.

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LIST OF ACRONYMS AND ABBREVIATIONS

APB	Acquisition Program Baseline
APUC	Average Production Unit Cost
BCA	Business Case Analysis
CER	Cost Estimation Relationship
COCOM	Combatant Commander
CONOPS	Concept of Operations
DoD	Department of Defense
FY	Fiscal Year
HALE	High Altitude Long Endurance
ISR	Intelligence, Surveillance, and Reconnaissance
JCTD	Joint Capabilities Technology Demonstrator
LCC	Life Cycle Cost
NCCA	Naval Center for Cost Analysis
nm	Nautical Miles
NMS	National Military Strategy
NSS	National Security Strategy
NPV	Net Present Value
NPVLCC	Net Present Value of Life Cycle Cost
O&S	Operations & Support
OMB	Office of Management and Budget
OCO	Overseas Contingency Operations
OMN	Operations and Maintenance, Navy
OPNAV	Chief of Naval Operations Staff
OPTAR	Operating Target
PPBES	Planning, Programming, Budgeting and Execution System
R&D	Research and Development
RDT&E	Research, Development, Testing and Evaluation
RR	Return Ratio = NPVLCC_candidate/NPVLCC_Magic

ROI	Return on Investment
USAF	United States Air Force
UAS	Unmanned Aircraft System
UAV	Unmanned Air Vehicle

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EXECUTIVE SUMMARY

The goal of this study is to conduct a business case analysis of a Medium Altitude Global ISR Communication (MAGIC) UAV system. The DoD has a number of UAVs both in operations as well as in various stages of research, development, production, and deployment. A brief survey of UAVs in the medium altitude ISR range is presented. The MAGIC platform is analyzed together with three other platforms. A cost model for RDT&E and O & S for the MAGIC is developed based on the available data for the other platforms. Cost estimates use key performance parameters from the published literature. Three scenarios are considered. Two parameters are developed as measures of effectiveness (MOE), namely, a Net Present Value of Life Cycle Cost (NPVLCC) and a return ratio defined as the ratio of NPVLCC of a platform to the NPVLCC of MAGIC.

A baseline case is developed with cost estimates for RDT&E, Average Production Unit Cost (APUC), discount factor (discount rate), dollar per flight hour ($/FH) and a scenario with a 500 nm range. Net present value (NPV) calculations use a 10-year time horizon. These values and sensitivity analysis parameters are shown in the Table 1.

	MAGIC RDTE	MAGIC APUC	Discount Rate (%)	$/FH	Range (nm)
Baseline	510*	17*	2.5	3.7*	500
Variation	300-510-1300	14-17-20	0.0-2.5-5.0	3.7	500-1000-2000-3000

Table 1. Baseline assumptions and sensitivity parameters. All costs are in FY10$M
*These values are estimated using historical data

The results shown in Table 2 indicate that MAGIC outperforms Reaper (MQ-9) and Global Hawk (RQ-4) for all reasonable values of input variables. Predator (MQ-1B) outperforms MAGIC under current MAGIC cost estimates. MAGIC becomes competitive over Predator when the RDT&E cost is about $300M (approximately 40% lower than the baseline $510M) or unit production costs are under $14M (approximately 20% lower than the baseline $17M).

In the 1000 nm range, MAGIC outperforms Predator, Reaper, and Global Hawk platforms. MAGIC dominates Global Hawk in 2000 nm and 3000 nm ranges. Other platforms do not meet range requirements. The results for a payload of 1000 lbs and 450 lbs are presented in Tables 3 and 4. The results show that Reaper is marginally better than MAGIC for the 500 nm range. MAGIC is preferred over Global Hawk in this range. At the range of 1000 nm MAGIC outperforms Global Hawk and is indifferent compared to Reaper. MAGIC dominates Global Hawk and Reaper platforms for 2000 nm range. MAGIC outperforms Global Hawk at 3000 nm range for this payload. The results for MAGIC is compared to Predator with a payload of 450 lbs are shown in Table 4. MAGIC is preferred over Predator in the 500 nm and dominates at 1000 nm range. Predator cannot compete in the 2000 nm and 3000 nm range.

Summarizing, MAGIC platform outperforms Reaper and Global Hawk for ISR capabilities with reasonable input values in the 500 nm range. Predator is preferred at this range with the present cost estimates of MAGIC. MAGIC is preferred platform over Reaper and Global Hawk in 1000 nm range and dominates Global Hawk in the 2000 and 3000 nm range. Further refinements in the cost estimates of RDT&E and O &S for MAGIC would be helpful in the next mile stone product decision-making process.

Summary of Baseline Case*
Return Ratios for Different Ranges - DoD SAR Data

Platforms	Range 500 nm	Range 1000 nm	Range 2000 nm	Range 3000 nm
Predator (MQ-1B) -MAGIC	0.88	1.24	CC	CC
Global Hawk-MAGIC	4.91	4.92	5.07	8.25
Reaper (MQ-9)-MAGIC	1.17	2.0	CC	CC

Return Ratio Very High Strongly Favors MAGIC

Return Ratio High Favors MAGIC

Return Ratio Marginal Borderline Case

- *Baseline Case: Average Production Unit Cost (APUC) = $17M; RDTE = $510M; Discount Factor = 0.025
- Return Ratio = NPVLCC_candidate/NPVLCC_MAGIC > 1 Favors MAGIC
- CC = Cannot Compete;

Table 2. Summary of Baseline case vs. Return Ratios (NPVLCC_CandidateUAV to NPVLCC_MAGIC) are given using DoD SAR data. CC - Cannot Compete

Summary of Baseline Case*
Return Ratios for Different Ranges, Payload=1000lbs**

Platforms	Range 500 nm	Range 1000 nm	Range 2000 nm	Range 3000 nm
Predator (MQ-1B) -MAGIC	DNA	DNA	DNA	DNA
Global Hawk-MAGIC	4.92	4.92	5.07	9.00
Reaper (MQ-9)-MAGIC	0.88	1.0	1.93	~~CC~~

Return Ratio Very High Strongly Favors MAGIC | Return Ratio Neutral | Return Ratio Marginal Borderline Case

- *Baseline Case: Average Production Unit Cost (APUC) = $17M; RDTE = $510M; Discount Factor = 0.025
- Return Ratio = NPVLCC_candidate/NPVLCC_MAGIC > 1 Favors MAGIC
- CC = Cannot Compete; DNA = Data Not Available
- **Data From USAF

Table 3. Summary of Baseline case vs. Return Ratios for 1000 lb payload

Summary of Baseline Case*
Return Ratios for Different Ranges, Payload=450 lbs**

Platforms	Range 500 nm	Range 1000 nm	Range 2000 nm	Range 3000 nm
Predator (MQ-1B) -MAGIC	1.24	3.53	CC	CC
Global Hawk-MAGIC	DNA	DNA	DNA	DNA
Reaper (MQ-9)-MAGIC	DNA	DNA	DNA	DNA

Return Ratio Very High Strongly Favors MAGIC

Return Ratio High Favors MAGIC

Return Ratio Marginal Borderline Case

- *Baseline Case: Average Production Unit Cost (APUC) = $17M; RDTE = $510M; Discount Factor = 0.025
- Return Ratio = NPVLCC_candidate/NPVLCC_MAGIC > 1 Favors MAGIC
- CC = Cannot Compete; DNA = Data Not Available;
- **Data From USAF

Table 4. Summary of Baseline case vs. Return Ratios for 450 lb payload

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I. INTRODUCTION

A. MOTIVATION

The military has seen increased use of the Unmanned Systems in all environments, land, sea, and air. These unmanned aircraft systems (UAS) have logged over 500,000 flight hours, unmanned ground vehicles (UGVs) have performed over 30,000 missions, and unmanned maritime systems (UMSs) (defined as unmanned undersea vehicles—UUVs, and unmanned surface vehicles—USVs) have protected the ports. These versatile and persistent systems perform reconnaissance, mine detection, surveillance, precision target designation, signals intelligence and host of other combatant commanders' tasks. Recognizing their value, OSD has issued a roadmap describing the future for the unmanned systems (OSD, 2009).

Pursuant to one of the goals presented in this roadmap (Goal 3), the USAF, U.S. Central Command (CENTCOM) and OSD have pursued a UAS for medium altitude deployment as a capabilities technology demonstrator. This is referred as the Medium Altitude Global ISR Communication (MAGIC) program with increased persistence and long endurance ISR capabilities. The USD (AT&L) approved and signed the Weapon Systems Acquisition Reform Product Support Assessment report (DoD, 2011). One of the recommendations of this report is to use analytical tools such as BCA in the life cycle product support decision making process. Accordingly, this thesis performs a business case analysis (BCA) of MAGIC to help support the decision making process.

B. BACKGROUND

The military has successfully leveraged the advances in the technology of UAS to counter the Global War on Terrorism as evidenced by their deployment in the Operations Enduring Freedom and Iraqi Freedom, and in Afghanistan. Reflecting the military strategy, DoD is committing more budget to develop and acquire unmanned systems. Table 1 shows the increasing role of UAS and resource allocation in the president's budget (FY11).

Unmanned Funding ($ Mil)							
Fiscal Year Defense Prog		FY11	FY12	FY13	FY14	FY15	Total
Air	RDTE	1,106.72	1,255.29	1,539.58	1,440.57	1,296.25	6,638.40
	PROC	3,351.90	2,936.93	3,040.41	3,362.95	3,389.03	16,081.21
	OM	1,596.74	1,631.38	1,469.49	1,577.65	1,825.45	8,100.71
Domain Total		6,055.36	5,823.59	6,049.48	6,381.17	6,510.72	30,820.32
Fiscal Year Defense Prog		FY11	FY12	FY13	FY14	FY15	Total
Ground	RDTE	0.00	0.00	0.00	0.00	0.00	0.00
	PROC	20.03	26.25	24.07	7.66	0.00	78.01
	OM	207.06	233.58	237.50	241.50	245.96	1,165.60
Domain Total		227.09	259.83	261.57	249.16	245.96	1,243.61
Fiscal Year Defense Prog		FY11	FY12	FY13	FY14	FY15	Total
Maritime	RDTE	29.69	62.92	65.72	48.60	47.26	254.19
	PROC	11.93	45.45	84.85	108.35	114.33	364.90
	OM	5.79	4.71	3.76	4.00	4.03	22.28
Domain Total		47.41	113.08	154.32	160.94	165.62	641.37
Fiscal Year Defense Prog		FY11	FY12	FY13	FY14	FY15	Total
All Unmanned	RDTE	1,136.41	1,318.21	1,605.29	1,489.16	1,343.52	6,892.59
	PROC	3,383.86	3,008.63	3,149.32	3,478.96	3,503.36	16,524.12
	OM	1,809.59	1,869.67	1,710.75	1,823.15	2,075.44	9,288.59
Domain Total		6,329.86	6,196.50	6,465.36	6,791.27	6,922.31	32,705.30

Table 1. President's Budget (FY2011) for Unmanned Systems($ Mil) (From DoD, 2011b)

Table 2 shows UAS platforms reported in the DoD UAS roadmap (DoD, 2011b). This document stresses the need for affordable and convergent systems and envisions DoD to acquire Joint and interoperable, software, architecture, payloads and sensors for UAS acquisitions. Unit cost is an important factor in enabling the commanders with risk taking in their tactics and techniques. As DoD goes ahead with acquiring these platforms, affordability is required additional KPP in the requirements for major weapons acquisitions (DoD, 2010b).

AIRCRAFT					
System	Lead Service	Primary JCA	Mission Capabilities	ACAT	Acquisition Status
GROUP 1					
RQ-16B T_Hawk	US Navy	N/A	ISR/RSTA, EOD	Non-ACAT	Other
Wasp	US Air Force	BA	ISR/RSTA	Non-ACAT	Other
RQ-11B Raven	US Army	BA	ISR/RSTA	IV(T)	Production
Puma AE	USSOCOM	N/A	ISR/RSTA, FP	III	Production/Sustainment
GROUP 2					
Scan Eagle	US Navy , US Marines	N/A	ISR/RSTA, Force Protection	Non-ACAT	Other
GROUP 3					
RQ-7B Shadow	US Army, US Marines	BA	ISR/RSTA, C3, Force Protection	II	Production
S 100	USSOCOM	N/A	ISR/RSTA, EW, Force Protection	III	Design &Development
STUAS RQ-21A	US Navy , US Marines	BA	ISR/RSTA, EOD, Force Protection	III	Design &Development
Viking 400	USSOCOM	N/A	ISR/RSTA, EW, Force Protection	III	Design &Development
GROUP 4					
MQ-5B Hunter	US Army	N/A	ISR/RSTA, C3, Log, PS/TCS, FP	N/A	Other
MQ-1C Gray Eagle	US Army	BA	ISR/RSTA, C3, Log, PS/TCS, FP	I D	Production
MQ-1B Predator	US Air Force	BA	ISR/RSTA, PS/TCS, FP	I D	Sustainment
MQ-8B VTUAV	US Navy		ISR/RSTA, ASW, SUW/ASUW,	I C	MS-C
GROUP 5					
MQ-4 BAMS	US Navy		ISR/RSTA, EW, PS/TCS, SUW/ASUW, FP	I D	Design &Development
MQ-9A Reaper	US Air Force	FA	ISR/RSTA, EW, PS/TCS, FP	I D	Production
RQ-4A Global Hawk	US Air Force	BA	ISR/RSTA, C3, PS/TCS	I D	Sustainment
RQ-4B Global Hawk	US Air Force	BA	ISR/RSTA, C3, PS/TCS	I D	Production/Sustainment
MR UAS	US Navy	N/A	TBD	N/A	Concept
UCLASS	US Navy	N/A	TBD	N/A	Concept
MQ-X	US Air Force	FA	ISR/RSTA, PS/TCS, FP	N/A	Concept
Group 4	US Marines	N/A	TBD	N/A	Concept

Table 2. DoD Unmanned Capabilities by Program (From DoD, 2011b)

C. RESEARCH QUESTIONS

There are two research questions addressed in this study.

1. Primary Research Question:

What is the business case for MAGIC compared to Predator (MQ-1B), Global Hawk (RQ-4 A/B), and Reaper (MQ-9)

2. Secondary Research Question:

What are the competing platforms for MAGIC including current and planned?

D. THESIS OUTLINE

Chapter I provides motivation, background and the purpose of the study. Chapter II describes the methodology adopted in this study; metrics developed and used in the analysis; and the assumptions used in the business case analysis. Chapter III presents unmanned ISR platforms that are available and planned. It also provides key system performance parameters. This chapter provides Cost Estimation Relationships (CERs) for the MAGIC platform. Chapter IV discusses the analysis of MAGIC and three other platforms for 500 nautical miles scenario. Chapter V describes the analyses for 1000 nm, 2000 nm and 3000 nm ranges. Chapter VI contains conclusions and recommendations.

II. METHODOLOGY, METRICS AND ASSUMPTIONS

A. INTRODUCTION

1. Overview

This chapter presents the methodology used in developing the BCA. It also contains the two metrics used in the assessment of alternatives. The assumptions used in developing the BCA and the metrics are in the next section.

B. METHODOLOGY

1. Business Case Analysis

As suggested in a DoD instruction (DoD, 2011), business case analysis helps in the product decision making process at different stages of its evolution. The analysis and approach is adopted from this guide and Lim's thesis (Lim, 2007). The BCA is adapted from the recommended steps as presented in Figure 1 (DoD, 2011).

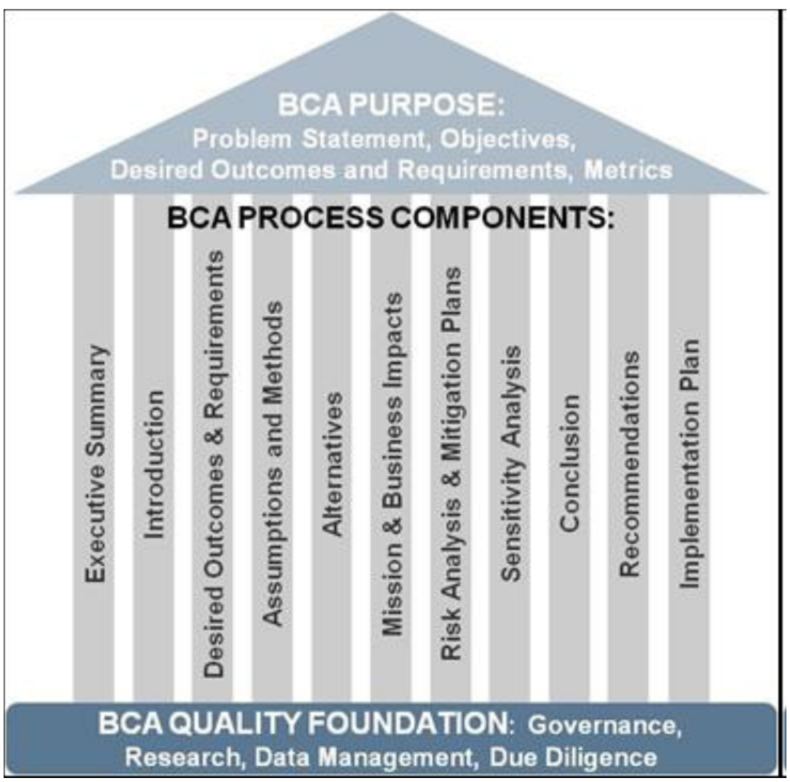

Figure 1. Business Case Analysis Process Components (from DoD, 2011)

2. Life Cycle Costs

Life Cycle Costs are defined as the sum of Research, Development, Test and Evaluation (RDT&E), procurement cost, O & S cost and disposal cost (DoD, 2011; Nussbaum, 2010).

C. METRICS

1. Net Present Value of Life Cycle Cost

The formula for the Net Present Value (NPV) is (Brealey, 2008)

$$NPV = \frac{FV}{(1+r)^n}$$

$$NPV = \text{NetPresentValue}$$

$$FV = \text{future value}$$

$$r = \text{interest rate}$$

$$n = \text{number of periods}$$

Future Value, in the above formula, is the total cost per year in future years. NPV of the total cost per year over the assumed life of the asset is the Net Present Value of the Life Cycle Cost (NPVLCC).

2. Return Ratio

Return ratio is the ratio between the NPVLCC of a given platform to the NPVLCC of MAGIC platform, given by

$$RR = \frac{NPVLCC\_Platform}{NPVLCC\_MAGIC}$$

$$RR = \text{Return Ratio}$$

$$NPVLCC\_platform = \text{NetPresent Value of Life Cycle Cost of a platform}$$

$$NPVLCC\_MAGIC = \text{NetPresent Value of Life Cycle Cost of MAGIC}$$

D. ASSUMPTIONS

The following assumptions are applicable in the development of the BCA.

- All costs are normalized to FY10 $M
- Baseline Case discount factor (discount rate) of 2.5% is used in the net present value (NPV) calculations per Office of Management & Business (OMB) guidance
- Time horizon is 10 years with 24/7 persistent ISR coverage

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III. SCENARIOS, PLATFORMS AND COST ESTIMATE RELATIONSHIPS (CERS)

A. INTRODUCTION

In this chapter, the analyses is presented for different scenarios considered for the BCA. The base line considered is for 500 nm scenario with other parameters defined in the section. The last section describes CERs for RDT&E and O & S costs for MAGIC.

B. SCENARIOS

There are four scenarios that were adapted from previous studies (Lim, 2007). These scenarios are 500 nm (base line range), 1000 nm (short range), 2000 nm (medium range) and 3000 nm (long range). These ranges represent operational conditions in areas of operations (AO) such as Afghanistan, North Korea, and Trans-Sahara regions.

C. PLATFORMS WITH ISR CAPABILITY

The present BCA addresses the platforms with Intelligence, Surveillance and Reconnaissance (ISR) capabilities in the medium altitude defined as 15,000 feet to 60,000 feet. Medium Altitude Global ISR and Communications (MAGIC) platform is the proposed candidate analyzed with other platforms. Tables 5 and 6 present platforms and their key performance parameters (DoD, 2009b; DoD, 2009c; DoD, 2009d; DoD, 2010a; BAMS, 2003; GAO, 2009). Table 7 gives notional additional data provided by USAF for analysis.

Platforms with ISR capability

	Length, ft	Wingspan , ft	Speed, Knots	Endurance, hrs	Range, nm	Altitude,ft
MQ-1 Predator A	27	49	70	40	400	25000
MQ-1B Predator	36	66	160	24	2000	45000
MQ-9 Reaper	36	66	240	14	3200	45000
ER/MP	28	56	135	36	200	29000
RQ-4 Global Hawk	48	131	330	31		60000
BAMS	48	131	310	30	9950	60000
Magic		132	70	120		20000

Analysis Completed

Table 5. Platforms with ISR Capabilities vs. Key Performance Parameters

Platforms with ISR capability (Cont'd)

	GTOW, lbs	Ext Payload	Int Payload, lbs	Remarks	Power,hp
MQ-1 Predator A	2300	200	450	Rotax 4 Cy Eng	
MQ-1B Predator	10000	3000	800	Honeywell TPE-331-10T	115
MQ-9 Reaper	10500	3000		Allison-Garret	950
ER/MP	3200	800		Thielert Centurion	135
RQ-4 Global Hawk	32250	4500		Rolls-Royce	950
BAMS	32350	2400	3200	Rolls-Royce AE3007 TF	
Magic	11000	1000			168

Table 6. Platforms with ISR Capabilities vs. Key Performance Parameters, contd.

USAF Data

	Payload-old, lbs	Payload-new, lbs	Endurance-old, Hrs	Endurance-new, Hrs
MQ-9 Reaper	3000	1000	14	21
RQ-4 GHawk	4500	1000	31	30
MAGIC	1000	1000	120	120
MQ-1B-Predator	800	450	24	16
MAGIC	1000	450	120	131

Table 7. Platforms with notional ISR capabilities vs. Key Performance parameters

D. COST ESTIMATION RELATIONSHIPS (CERS) FOR MAGIC

1. Cost Estimates for RDT&E for MAGIC

This section develops CERs relating the two key parameters for UAVs and applies it to MAGIC based on its key performance parameters.

The cost of fuel per flight hour for available UAVs is extracted from Selected Acquisition Reports (SARs), Acquisition Program Baseline (APBs) and other published data. Two relationships are developed for estimating Operations & Support (O & S) costs for MAGIC. The first method develops dollar/flight hour/Average Production Unit Cost (APUC) as a function of engine power. The second method develops dollar/flight hour as a function of Gross Take Off Weight (GTOW). The data for the CER is presented in the Table 8 (DoD 2009b, DoD 2009c, DoD 2009d, DoD 2009e, BAMS 2003). The x-axis on the graph is the product of payload and endurance given by

Payload (thousands of lbs) * Endurance (Hours)

The RDT&E/APUC is related to the Kilo-pound-Payload-Hr and shown as a graph. The value of the ratio RDT&E/APUC for MAGIC from the graph is 26 and approximated conservatively to 30. This parameter is used in calculating the RDT&E cost for a chosen APUC.

2. Cost Estimates for O & S for MAGIC

Two methods present calculations of the CER for O & S for MAGIC. The O & S cost is the average of the two methods. The first method uses the ratio of dollar cost of fuel per APUC as a function of the horsepower. The second relation plots dollar cost of fuel for flight hour as a function of the GTOW. The values of KPP of the MAGIC in the graph gives \$3.7M (FY10 \$M) per year as O & S cost.

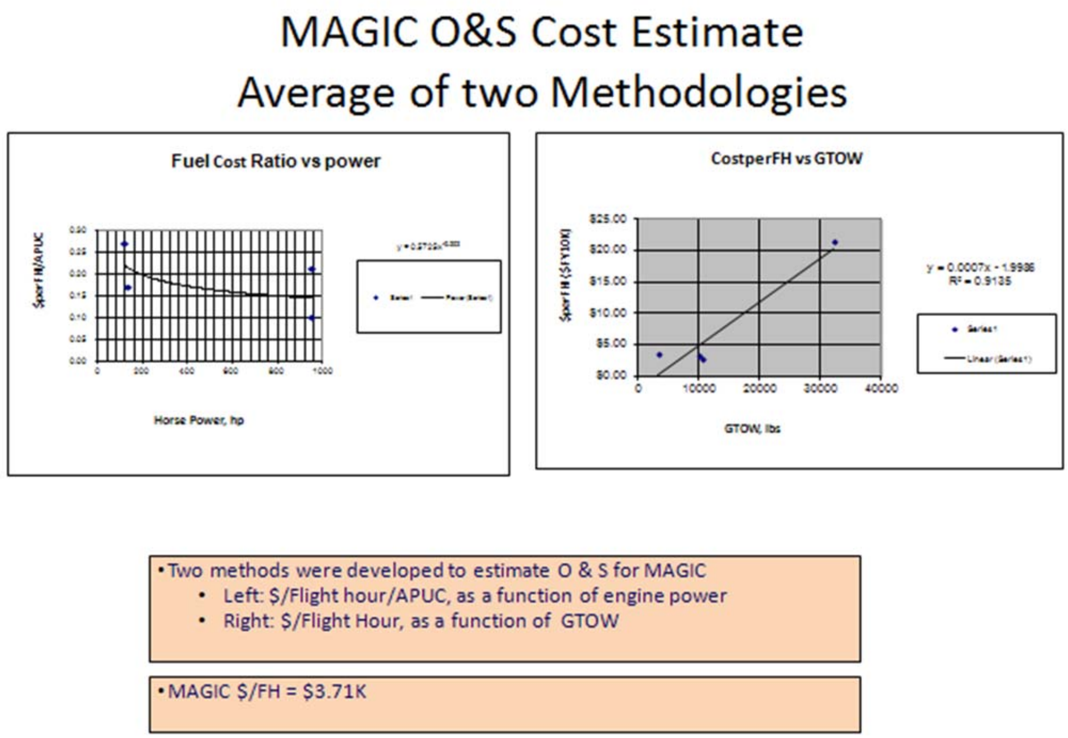
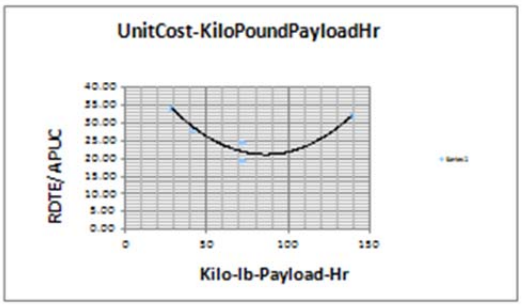


Figure 2. CER for O & S for MAGIC: Left graph is the fuel cost ratio vs power and Right graph is Cost per Flight Hour vs. GTOW

MAGIC Cost Estimate

The Relationship Between RDTE and Unit Production Costs for UAVs

		RDT&E	APUC	PAUC	RDTE/APUC	Endurance, Hrs	Payload, lbs	GTOW, lbs	RDTE/APUC	Kilo-Pound-Payload-Hrs
1	Predator	282.1	11.47	13.94	24.58	24	3000	10000	24.58	72
2	Reaper, MQ-9	778.8	27.50	25.13	28.32	14	3000	10500	28.32	42
3	ER/MP	706.4	20.61	31.56	34.27	36	800	3200	34.27	28.8
4	GlobalHawk-RQ-4	3233.6	100.84	144.38	32.07	31	4500	32250	32.07	139.5
5	BAMS	2410	124.56	n/a	19.35	30	2400	32350	19.35	72
6	MAGIC					120	1000	11000		120



Observation:
•The Kilo-Pound-Payload-Hrs parameter for MAGIC = 120;
•From the graph, the ratio of RDTE/APUC = 26

Table 8. Cost estimate Relationship based on RDT&E and APUC for UAVs

3. Summary

Summarizing, this chapter presented UAV platforms in the medium altitude with key performance parameters. Cost estimate relationships for MAGIC are developed based on historical data. Two Cost estimate relationships to determine O & S cost based on horse power and GTOW are developed. Further, a ratio defined as RDT&E/APUC for MAGIC is developed. This information is used in calculating annual costs and life cycle cost.

IV. ANALYSIS FOR 500 NM RANGE

This chapter provides analysis of MAGIC compared to other three platforms for a 500 nm scenario. The measures of effectiveness described earlier are calculated and presented for the baseline case. Sensitivity analysis is given by varying the key parameters.

A. MAGIC COMPARED WITH PREDATOR

This section describes the analysis of MAGIC and predator for 500 nm scenario. Table 9 gives the key performance parameters for the MAGIC and Predator.

Analysis – Base Case
Predator Vs Magic, 500nm
Key Performance Parameters

Parameter	Predator	MAGIC
Endurance, Hrs	24	120
Speed, Knots	160	70
Range, nm	500	500
Payload, lb	3000	1000
GTOW, lbs	10,000	11,000
No. of UAVs Required	5*	3*

•Values rounded up.

Table 9. Key Performance Parameters for MAGIC and Predator (*Values are rounded up)

Net Present Value of
Life Cycle Cost (NPVLCC)
Predator-MAGIC, 500 nm

	Predator	MAGIC	Return Ratio
Fleet Size Required	5	3	
Sorties per Year	523	84	
Investment Cost ($FY10M)			
RDT&E	$0	$300.	
Procurement	$57	$42	
Total Investment	$57	$342	
O & S Cost (Annual)	$136	$90	
10 Year Life Cycle Cost			
Investment	$57	$342	
O & S	$1,192	$783	
Total LCC	**$1,249**	**$1,125**	**1.11**

$$RR = ReturnRatio = \frac{NetPresent\ Value\ LCC\_Predator}{NetPresent\ Value\ LCC\_MAGIC} = 1.11$$

>1, Favors MAGIC

Table 10. Net Present Value of Life Cycle Costs for MAGIC and Predator for 500nm

The Table 10 shows the calculations for the NPVLCC for the 500 nm range. The return ratio of 1.11 favors MAGIC for this baseline case. Table 11 shows the values for sensitivity analysis using the perturbations from the baseline. The RDT&E, APUC, and discount factors are perturbed and NPVLCC and RR are computed.

Sensitivity Analysis
Predator-MAGIC, 500 nm

	RDTE (FY10 $M)	APUC (FY10 $M)	Discount Rate
Baseline	510	17	0.025
Parameter Variations	300-510-1300	14-17-20	0.0-0.025-0.05

Example: RDTE = 510, APUC = 17, df = 0.025

$$RR = ReturnRatio = \frac{NetPresent\ Value\ LCC\_Predator}{NetPresent\ Value\ LCC\_MAGIC} = \frac{1249}{1415} = 0.88,\ Predator$$

Table 11. Sensitivity Analysis of MAGIC and Predator for 500 nm

The baseline case uses the RDT&E cost of $510M, APUC value of $17M, and discount factor of 2.5%. The sensitivity values have three each for RDT&E, APUC, and discount rate as in the table.

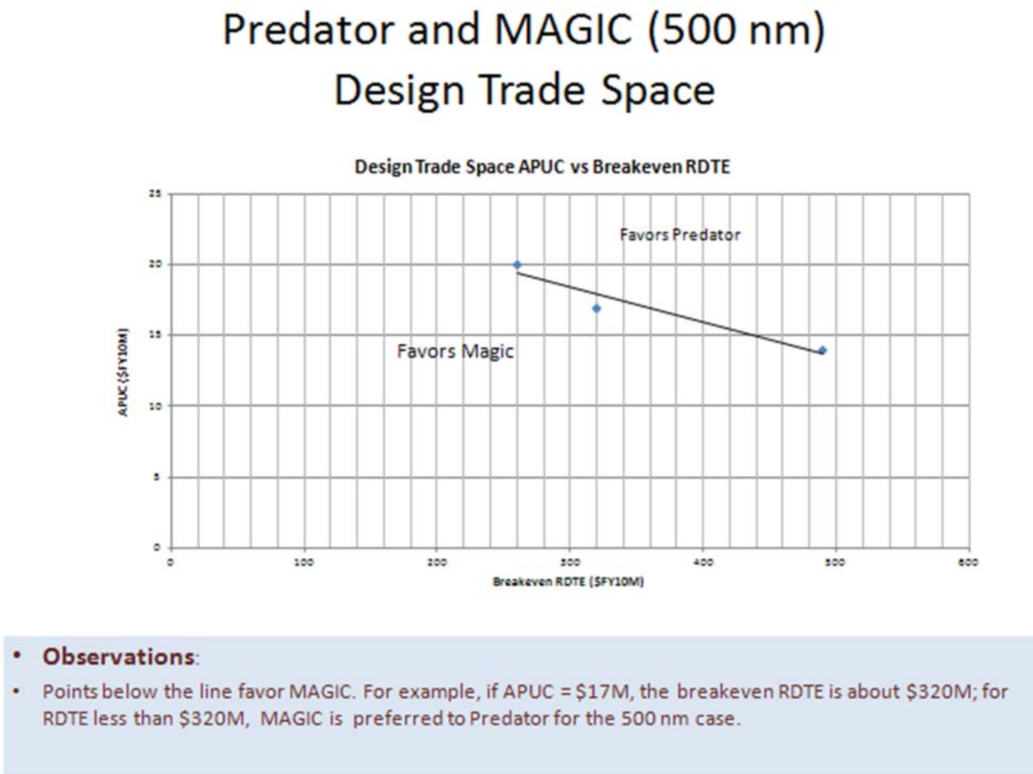


Figure 3. Sensitivity Analysis of MAGIC and Predator for 500 nm range

The Figure 3 shows variation of APUC with breakeven RDTE. The breakeven RDTE is the RDTE value corresponding to a return ratio of 1. As an example, for an APUC value of $17M, the breakeven RDTE value is about $320M. The figure shows that for RDTE of less than $320M, MAGIC favors Predator.

B. MAGIC COMPARED WITH GLOBAL HAWK

This section describes the analysis of MAGIC and Global Hawk for 500 nm scenario. Table 12 presents the key parameters for the two platforms.

Analysis – Base Case
Global Hawk Vs Magic
Key Performance Parameters, 500 nm

Parameter	Global Hawk	MAGIC
Endurance, Hrs	31	120
Speed, Knots	330	70
Range, nm	500	500
Payload, lb	3000	1000
GTOW, lbs	10,000	11,000
No. of GH Required	4	3

Calculations based on Cruise Speed, Endurance, Maintenance Time, No. of UAVs in the Area of Operations, No. of required spare UAVs.

Table 12. Key Performance Parameters for MAGIC and Global Hawk

The Table 13 presents the NPVLCC for the two platforms. The return ratio favors MAGIC for the baseline case parameters. The RDT&E, APUC, and discount factors are perturbed and Figure 4 presents the results of APUC as breakeven RDT&E cost is varied. Pairs of values to the left of the curve favor MAGIC and to the right of the curve Global Hawk is favored. As an example, consider an APUC of $15M, and read the breakeven RDT&E value of $6.13B from the left graph. This indicates that MAGIC is favored over Global Hawk for all values of RDT&E less than $6.13B for an APUC cost of $15M. Similarly, for a discount factor of 0.03, the breakeven RDT&E is observed as $2.14B. This reading indicates MAGIC is preferred over Global Hawk for all values of RDT&E less than $2.14B for a discount factor of 0.03.

NPVLCC

Global Hawk – MAGIC (500 nm)

	GLOBAL HAWK	MAGIC	Return Ratio
Fleet Size Required	4	3	
Sorties per Year	325	84	
Investment Cost ($FY10M)			
RDT&E	$0	$510	
Procurement	$403	$51	
Total Investment	$403.35	$561	
O & S Cost (Annual)	$748.59	$98	
10 Year NPV Life Cycle Cost			
Investment	$403	$561	
O & S	$6,552	$854	
Total NPV-LCC ($FY10M)	$6,955	$1,415	4.92

$$\text{Return Ratio} = \frac{\text{NetPresent Value LCC\_GlobalHawk}}{\text{NetPresent Value LCC\_MAGIC}} = 4.92$$

>1, Favors MAGIC

Table 13. NPVLCC analysis for the MAGIC and Global Hawk

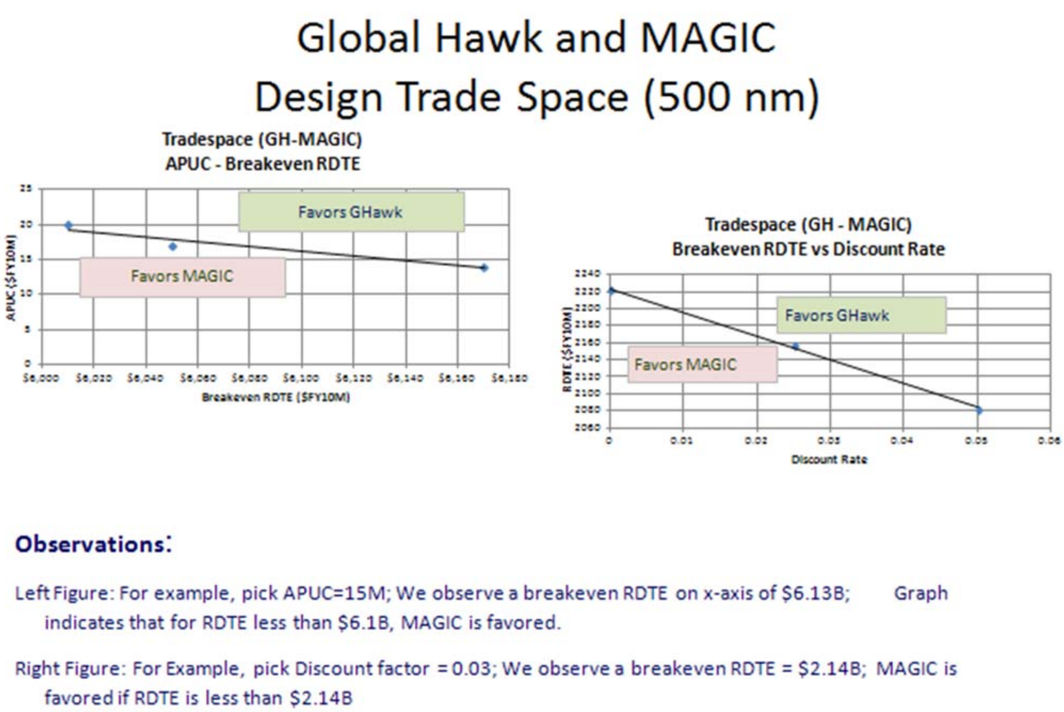


Figure 4. Sensitivity Analysis for MAGIC and Global Hawk platforms

C. MAGIC COMPARED WITH REAPER

This section describes the analysis of MAGIC and Reaper for 500 nm scenario. Table 14 gives the key performance parameters for MAGIC and Reaper platforms.

Analysis – Base Case
Reaper (MQ-9) Vs MAGIC
Key Performance Parameters, 500 nm

Parameter	Reaper	MAGIC
Endurance, Hrs	14	120
Speed, Knots	240	70
Range, nm	500	500
Payload, lb	3000	1000
GTOW, lbs	10,500	11,000
No. of UAVs Required	7	3

Calculations based on Cruise Speed, Endurance, Maintenance Time, No. of UAVs in the Area of Operations, No. of required spare UAVs.

Table 14. Key Performance Parameters for MAGIC and Reaper platforms

Table 15 shows the calculations for NPVLCC and the Return Ratio for these platforms in. The RR favors MAGIC for the baseline case at 500 nm range. The RDT&E, APUC, and discount factors are perturbed to analyze sensitivity to these parameters. Figure 5 shows the variations of these parameters. The graph on the left shows the variation of APUC with breakeven RDT&E. The pairs of points to the left of the curve favor MAGIC and favor Reaper to the right of the curve. The graph on the right shows the variation of breakeven RDT&E with discount factor.

NPVLCC
Reaper- MAGIC

	Reaper (MQ-9)	MAGIC	Return Ratio
Fleet Size Required	7	3	
Sorties per Year	992	84	
Investment Cost ($FY10M)			
RDT&E	0	$510	
Procurement	$193	$51	
Total Investment	$193	$561	
O & S Cost (Annual)	$167	$98	
10 Year NPV Life Cycle Cost			
Investment	$193	$561	
O & S	$1,461	$854	
Total NPV-LCC ($FY10M)	**$1,654**	**$1,415**	**1.17**

$$\text{Return Ratio} = \frac{\text{NetPresent Value LCC\_Reaper}}{\text{NetPresent Value LCC\_MAGIC}} = 1.17$$

>1, Favors MAGIC

Table 15. NPVLCC and Return Ratio for the MAGIC and Reaper for the baseline case

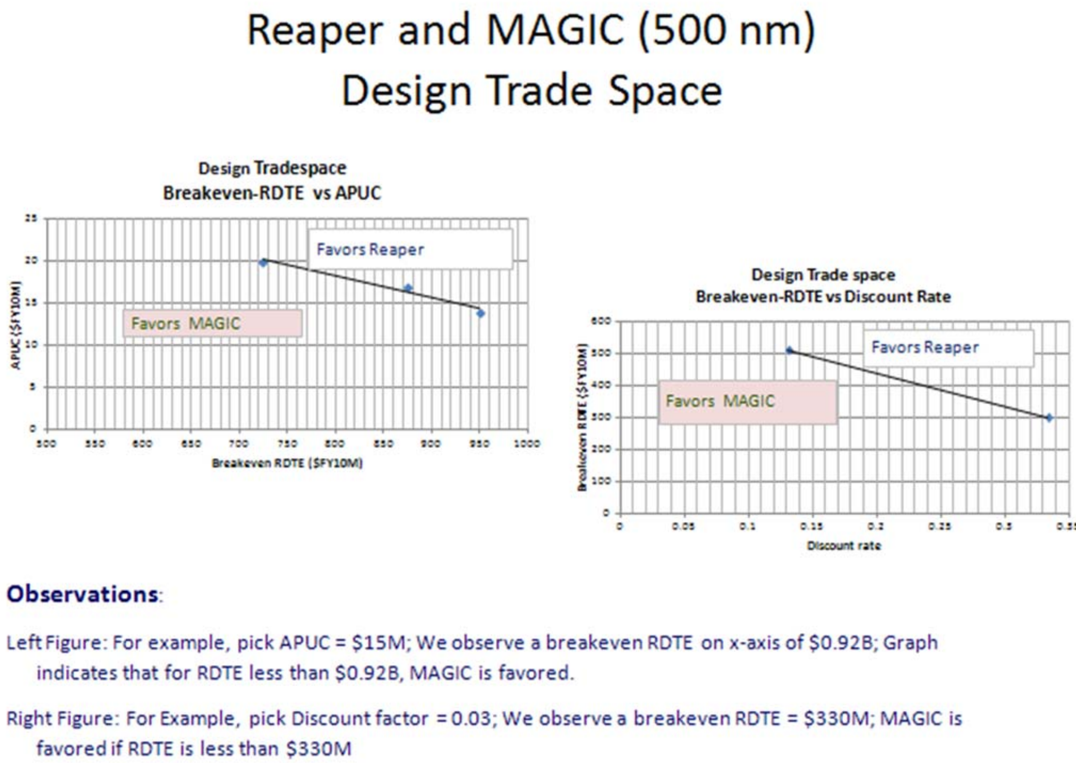


Figure 5. Sensitivity Analysis for MAGIC and Reaper for Baseline case for 500 nm range

D. SUMMARY OF BASELINE CASE FOR 500 NM RANGE

The baseline case has $510M for RDT&E, $17M for APUC, and a discount factor of 2.5% with a 10-year time horizon. MAGIC outperforms Global Hawk and Reaper for the baseline case with reasonable input values. Predator is preferred over MAGIC with the present cost estimates. The sensitivity analysis shows that if RDT&E costs are about $320M (40% reduced from $510M) then MAGIC is preferred. The sensitivity analyses also show that MAGIC is preferred over Global Hawk and Reaper platforms.

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V. ANALYSIS FOR 1000, 2000, AND 3000 NM RANGE

This chapter presents analysis for the MAGIC compared with the three ISR platforms for the 1000, 2000, and 3000 nm scenarios. The baseline case assumptions of RDT&E, APUC, and O & S cost is same for these ranges. The sensitivity analysis parameters have the same variations as the 500 nm range.

A. MAGIC AND PREDATOR FOR 1000 NM RANGE

Figure 6 presents the results of the analysis for this range. The x-axis has the breakeven RDT&E (BE-RDT&E) plotted against APUC. The BE-RDT&E indicates the RDT&E cost that is indifferent to both the platforms. As an example, for an APUC cost of $15M, the BE-RDT&E value from the graph is seen to be $1B. MAGIC is favored for $15M APUC for all values of the RDT&E cost less than $1B.

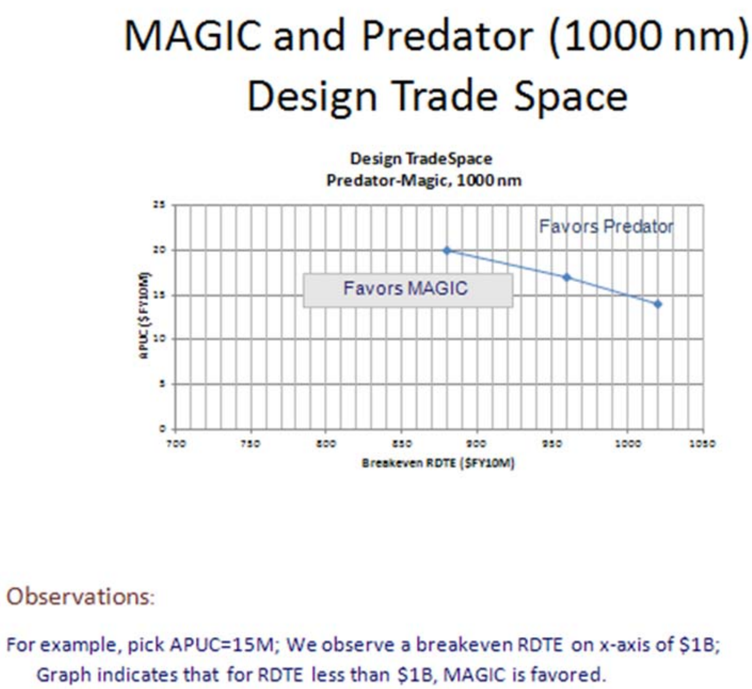

Figure 6. Design Trade Space with APUC vs. Breakeven RDT&E for MAGIC and Predator for 1000 nm range

B. MAGIC AND REAPER FOR 1000 NM RANGE

Figure 7 shows the design trade space for MAGIC and Reaper in this range. As an example, for an APUC value of $15M, the breakeven RDT&E is seen from the graph to be $1.98B. This indicates MAGIC is preferred over Reaper for RDT&E cost less than $1.98B for an APUC of $15M.

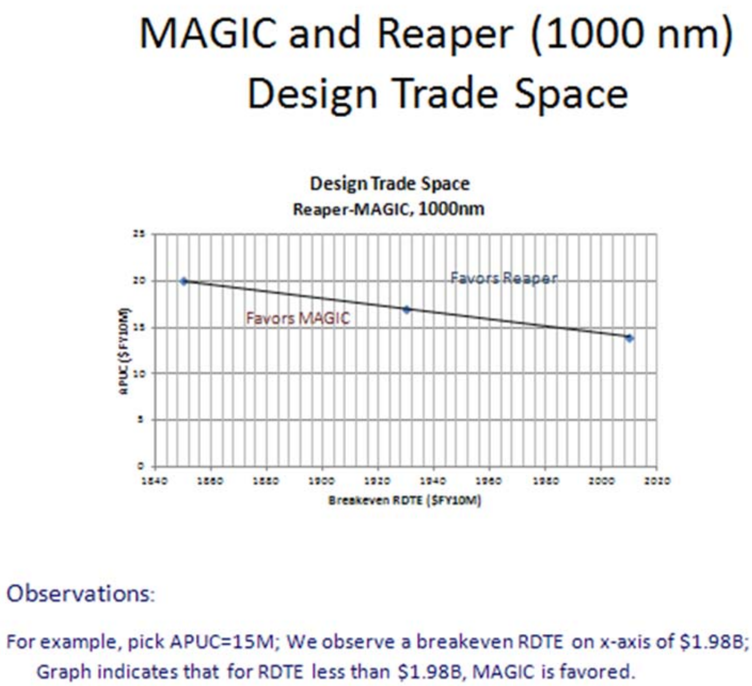

Figure 7. Design Trade Space for MAGIC and Reaper for 1000 nm range

C. ANALYSIS FOR MAGIC AND GLOBAL HAWK FOR 1000 NM RANGE

Figure 8 presents the results of the analysis for these platforms for the 1000 nm scenario. The left graph in the figure shows the design trade space with APUC and BE-RDT&E as parameters. As an example, an APUC value of $15M corresponds to a BE-RDT&E cost of $6.13B from the graph. This implies that MAGIC is preferred over Reaper for all values of RDT&E cost less than $6.13B for a chosen APUC value of $15M.

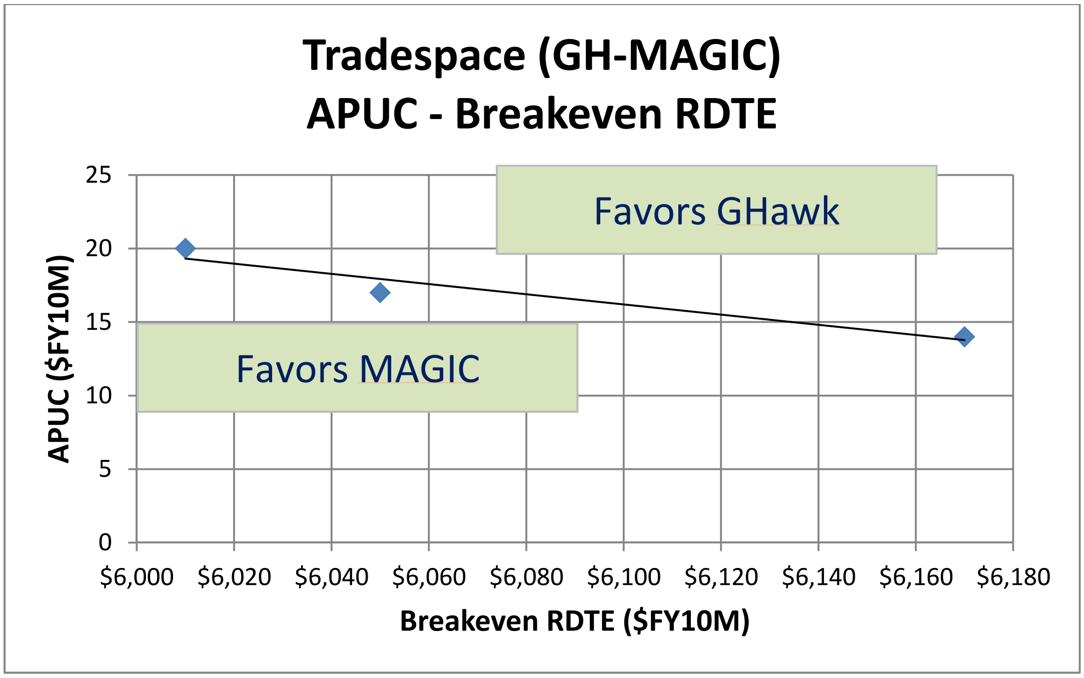

Figure 8. Trade space for MAGIC and Global Hawk for 1000 nm range

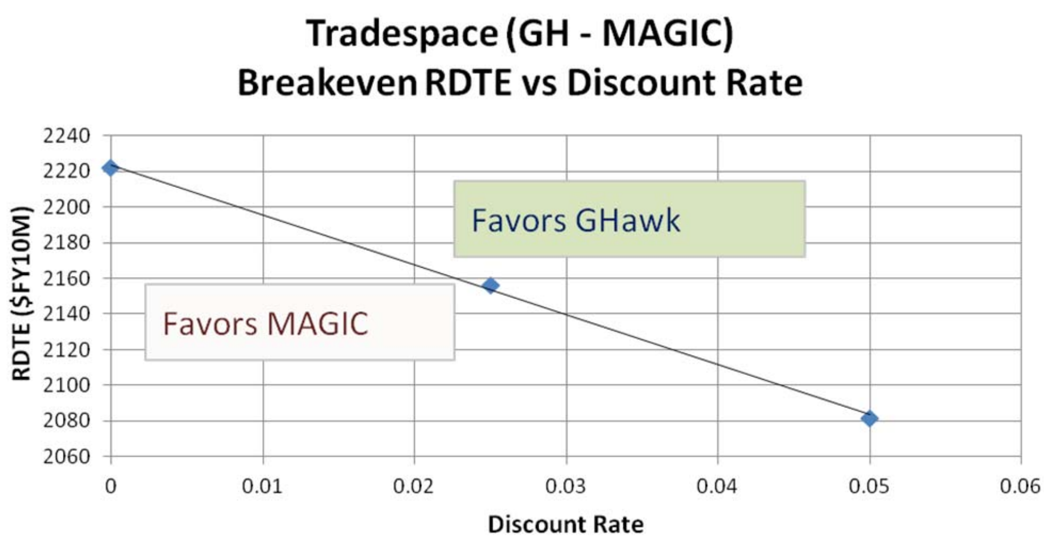

Figure 9. Trade space for MAGIC and Global Hawk for 1000 nm range with RDT&E vs discount factor

Figure 9 presents results with RDT&E and discount factor as parameters for these two platforms. As an example, for a discount factor of 0.03, MAGIC is favored over Global Hawk for all values of the RDT&E cost less than $2.13B.

D. ANALYSIS OF MAGIC FOR 2000 NM RANGE

This section presents analysis for MAGIC compared with Global Hawk platform. Other platforms cannot compete with the key performance parameters. Figure 10 presents the design trade space for MAGIC and Global Hawk. As an example, for an APUC of $15M, the graph provides a breakeven RDT&E of $7.56B. MAGIC is favored for all values of RDT&E under $7.56B for a selected APUC of $17M.

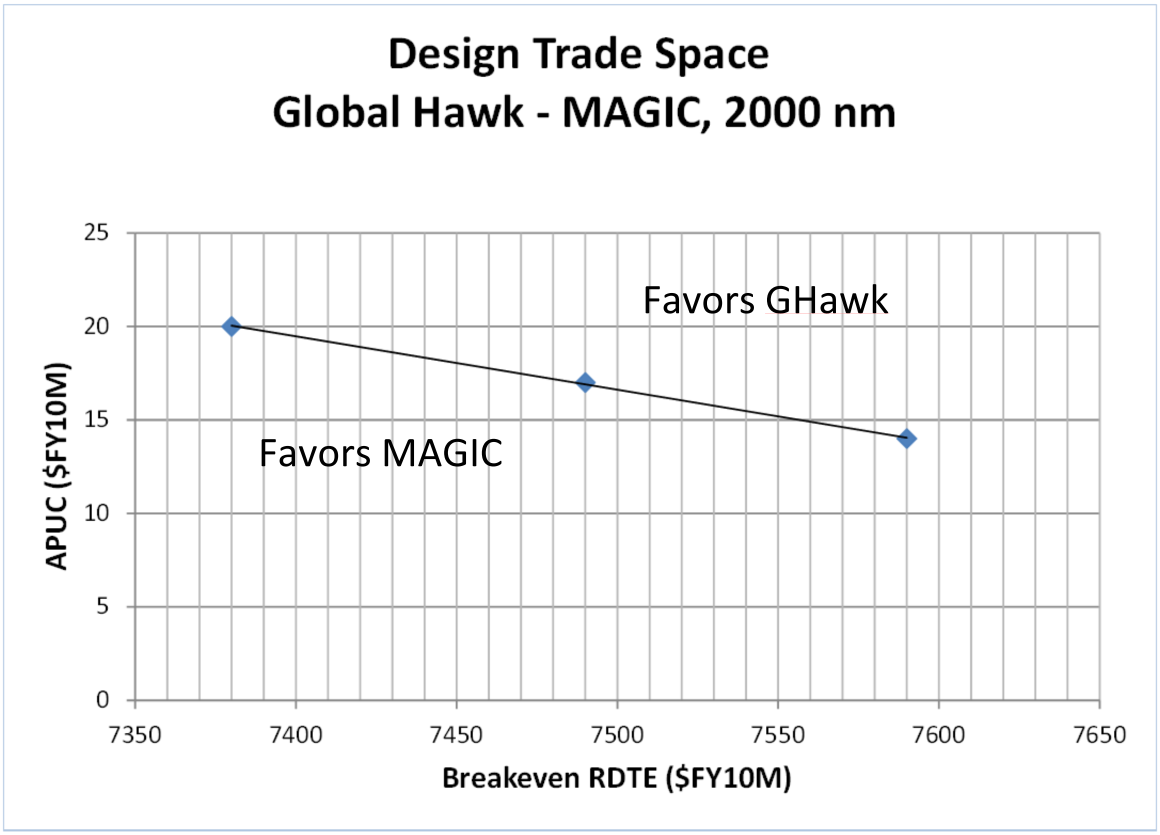

Figure 10. Design Trade Space for MAGIC and Global Hawk for 2000 nm range

E. ANALYSIS OF MAGIC FOR 3000 NM RANGE

This section provides analysis for MAGIC compared with Global Hawk. Other platforms cannot compete with the given key performance parameters. Figure 11 shows the resulting design trade space. As an example, for an APUC of \$15M, the breakeven RDT&E is \$17.42B. MAGIC is preferred for all values of RDT&E cost less than \$17.32B for the selected APUC of \$17M.

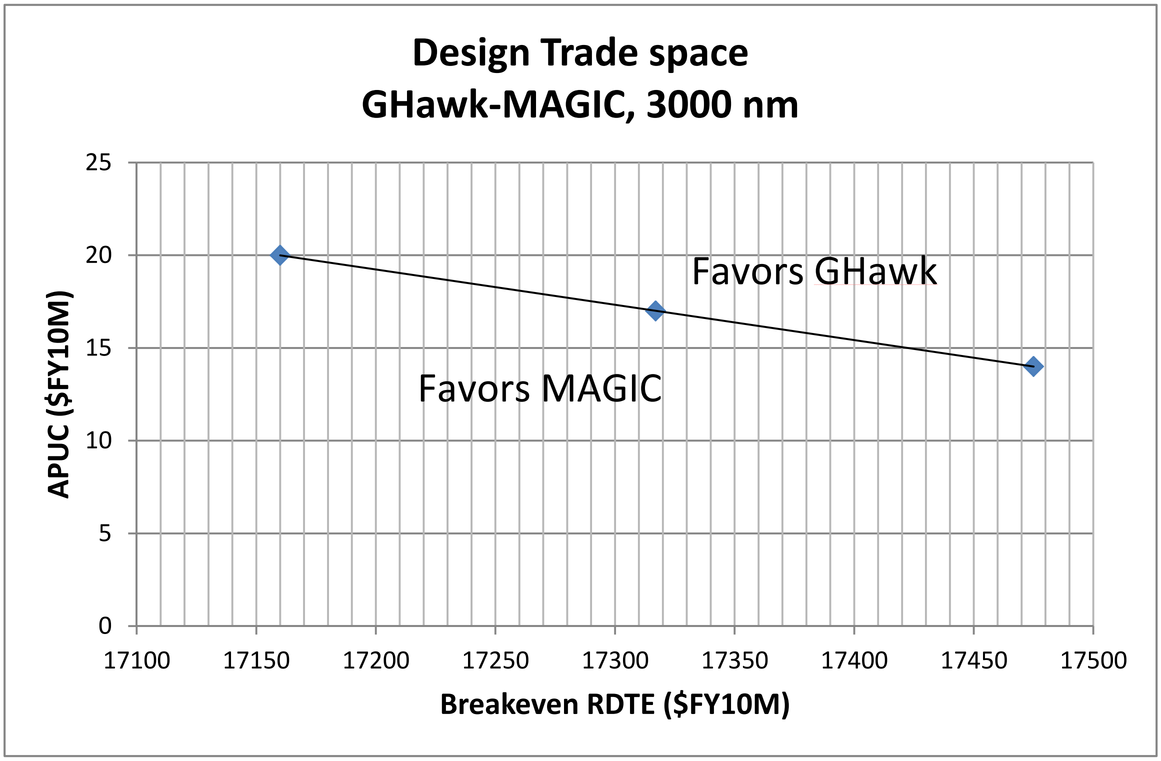

Figure 11. Design Trade Space for MAGIC and Global Hawk for 3000 nm range

F. ADDITIONAL DATA ANALYSIS

The sensitivity analyses for MAGIC with Predator, Reaper and Global Hawk for additional values are documented in Appendices A, B, and C.

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VI. CONCLUSIONS AND RECOMMENDATIONS

This chapter presents conclusions and recommendations based on the data and analysis of MAGIC and other three platforms. The measures of effectiveness used in the comparisons are Net Present Value of Life Cycle Cost and the Return Ratio (RR), which is the ratio of NPVLCC_candidate and NPVLCC_MAGIC. The sensitivity analysis parameters are RDT&E cost, APUC, and discount factor.

A. CONCLUSIONS

1. Primary Research Question

The return ratio (RR) is used to compare the platform relative economic feasibility. The results indicate that MAGIC outperforms Reaper (MQ-9) and Global Hawk (RQ-4) for all reasonable values of input variables. Predator (MQ-1B) outperforms MAGIC under current MAGIC cost estimates. MAGIC becomes competitive over Predator when the RDT&E cost is about $300M (approximately 40% lower than baseline $510M) or unit production costs are under $14M (approximately 20% lower than baseline $17M).

In the 1000 nm range, MAGIC outperforms Predator, Reaper, and Global Hawk platforms. MAGIC dominates Global Hawk in 2000 nm and 3000 nm ranges. Other platforms do not meet range requirements. The results for a payload of 1000 lbs and 450 lbs show similar trends. The results show that Reaper is marginally better than MAGIC for the 500 nm range. MAGIC is preferred over Global Hawk in this range. At the range of 1000 nm MAGIC outperforms Global Hawk and is indifferent compared to Reaper. MAGIC dominates Global Hawk and Reaper platforms for 2000 nm range. MAGIC outperforms Global Hawk at 3000 nm range for this payload. The results for MAGIC compared to Predator with a payload of 450 lbs indicate that MAGIC is preferred over Predator in the 500 nm and dominates at 1000 nm range. Predator cannot compete in the 2000 nm and 3000 nm range.

Summarizing, MAGIC platform outperforms Reaper and Global Hawk for ISR capabilities with reasonable input values in the 500 nm range. Predator is preferred at this range with the present cost estimates of MAGIC. MAGIC is preferred platform over Reaper and Global Hawk in 1000 nm range and dominates Global Hawk in the 2000 and 3000 nm range. Further refinements in the cost estimates of RDT&E and O &S for MAGIC would be helpful in the next mile stone decision-making process.

2. Secondary Research Question

There are several UAV platforms under various stages acquisition cycle. Some salient ones besides the platforms considered in this study include BAMS, Hunter, ER/MP and Vulcan. Their characteristics and key performance parameters are given in the roadmap and other studies (DoD, 2009a; Bowman & Brown, 2008; GAO 2009; Drew et al., 2005).

B. RECOMMENDATIONS

The present study suggests that MAGIC is preferred over the other platforms for the ISR mission requirements with the assumptions of the baseline and the scenarios.

APPENDIX A. ADDITIONAL RESULTS FOR MAGIC AND PREDATOR

The following tables and graphs support the analysis of MAGIC compared with Predator platform. The tables and figures have the same meanings and interpretations as the main chapters.

Return Ratio Table,
Predator vs Magic, 500 nm

Sensitivity Analysis	$FY10M	$FY10M	$FY10M	
		Predator	MAGIC	NPVLCC-Predator /NPVLCC-Magic
RDTE:$300M, $510M, $1000M	RDTE			
Total NPV LCC	$300.00	$1,419.00	$1,326.35	1.07
Dis=0.0; APUC=$17M	$510.00	$1,419.00	$1,536.35	0.92
	$1,300.00	$1,419.00	$2,326.00	0.61
Total NPV LCC	$300.00	$1,249.00	$1,205.00	1.04
Dis=0.025; APUC=$17M	$510.00	$1,249.00	$1,414.64	0.88
	$1,300.00	$1,249.00	$2,205.00	0.57
Total NPV LCC	$300.00	$1,109.00	$1,104.14	1.00
Dis=0.05; APUC=$17M	$510.00	$1,109.00	$1,314.14	0.84
	$1,300.00	$1,109.00	$2,104.00	0.53
Total NPV LCC	$300.00	$1,419.00	$1,237.07	1.15
Dis=0; APUC = $14M	$510.00	$1,419.00	$1,447.07	0.98
	$1,300.00	$1,419.00	$1,937.07	0.73
Dis=0.025; APUC = $14M	$300.00	$1,249.00	$1,125.37	1.11
	$510.00	$1,249.00	$1,335.37	0.94
	$1,300.00	$1,249.00	$1,825.37	0.68
Dis=0.05; APUC = $14M	$300.00	$1,109.00	$1,033.15	1.07
	$510.00	$1,109.00	$1,243.15	0.89
	$1,300.00	$1,109.00	$2,033.00	0.55
Total NPV LCC	$300.00	$1,419.00	$1,415.64	1.00
Dis=0; APUC = $20M	$510.00	$1,419.00	$1,625.64	0.87
	$1,300.00	$1,419.00	$2,115.64	0.67
Dis=0.025; APUC = $20M	$300.00	$1,249.00	$1,283.90	0.97
	$510.00	$1,249.00	$1,493.90	0.84
	$1,300.00	$1,249.00	$2,284.00	0.55
	275			
Dis=0.05; APUC = $20M	$300.00	$1,109.00	$1,175.14	0.94
	$510.00	$1,109.00	$1,385.14	0.80
	$1,300.00	$1,109.00	$2,175.00	0.51

Table 16. Return Ratio data for MAGIC and Predator for 500 nm

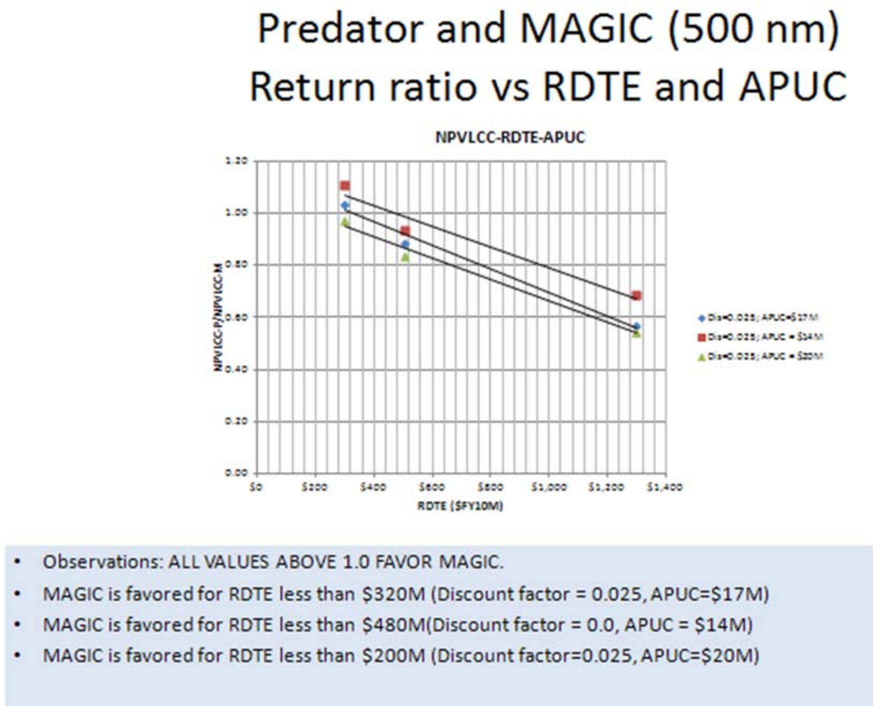

Figure 12. Trade space for MAGIC and Predator using RR, RDTE and APUC for 500 nm

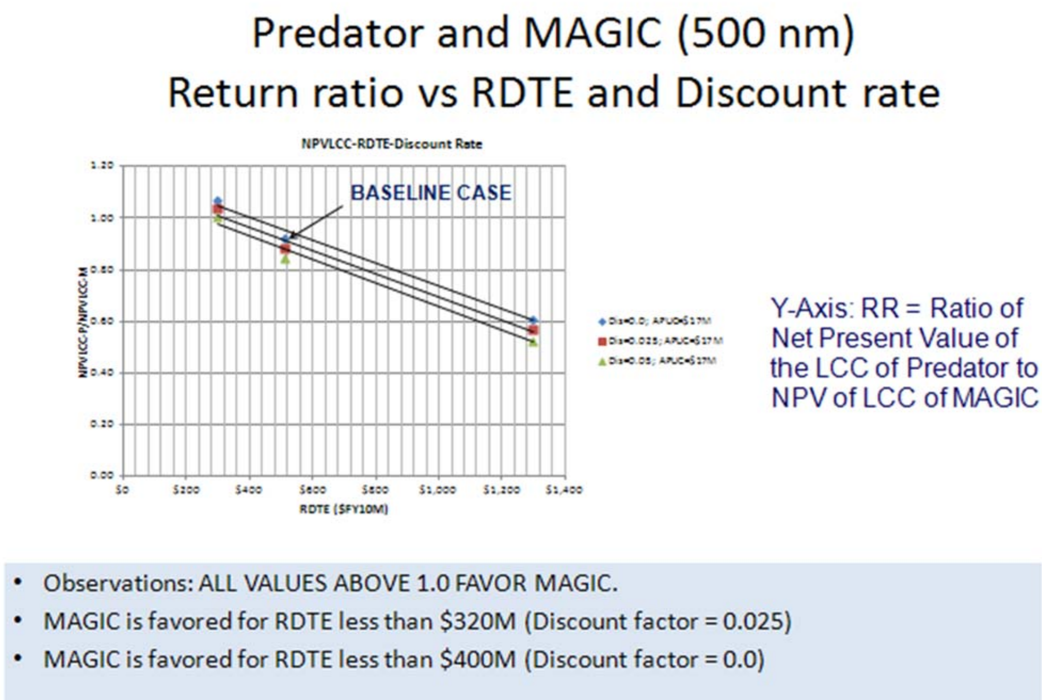

Figure 13. Design Trade Space for MAGIC and Predator using RR with RDTE varying discount factors for 500 nm range

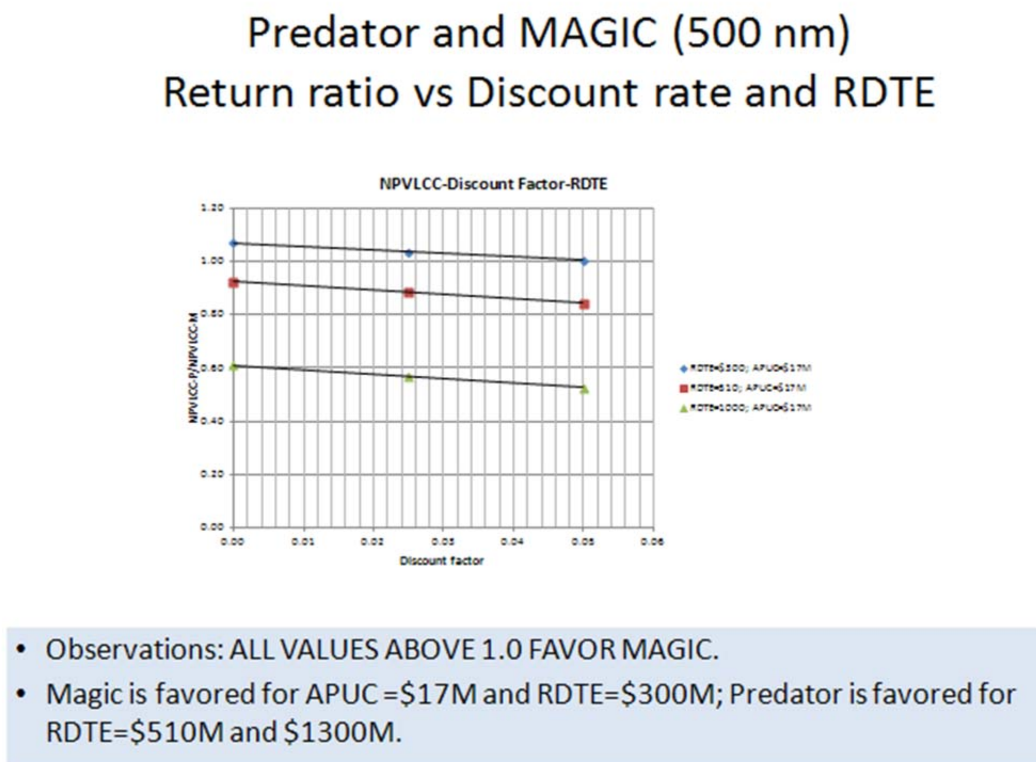

Figure 14. Design Trade Space for MAGIC and Predator using RR vs. discount factor varying RDT&E cost for 500 nm range

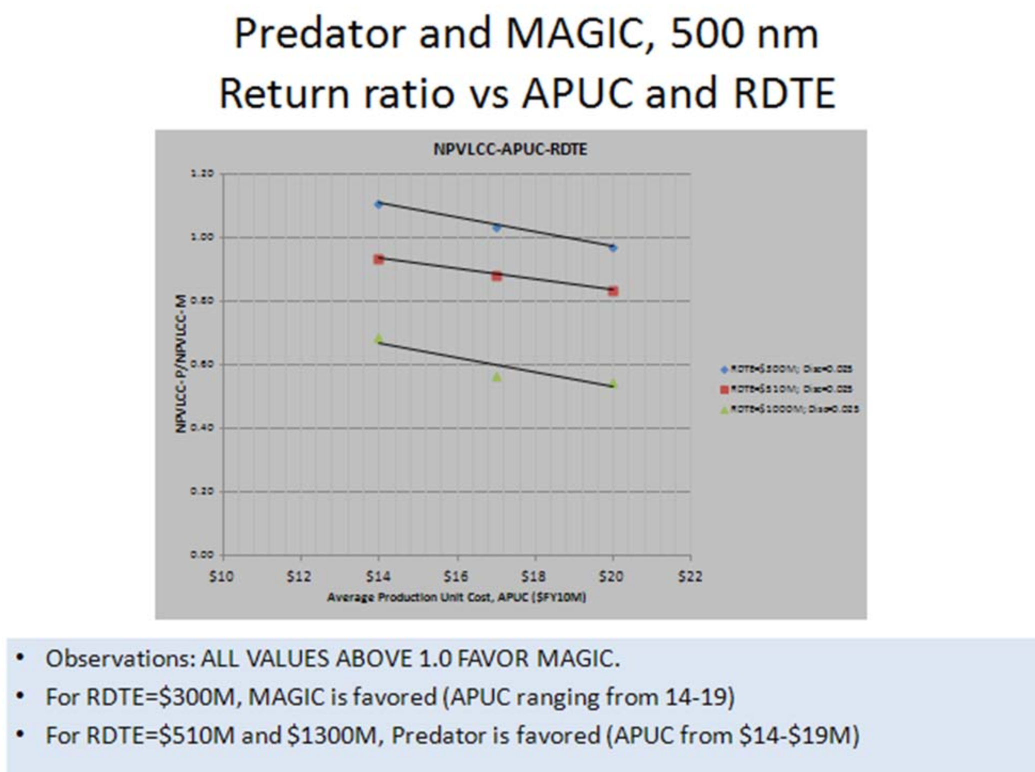

Figure 15. Design Trade Space for MAGIC and Predator using RR vs. APUC varying RDT&E for 500 nm range

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APPENDIX B. ADDITIONAL RESULTS FOR MAGIC AND GLOBAL HAWK

This appendix presents additional results for MAGIC and Global Hawk platforms. The tables and graphs have the same interpretations as in the main chapters.

Return Ratio, MAGIC-Global Hawk, 500 nm

Sensitivity Analysis	$FY10M	$FY10M		$FY10M	
		GlobalHawk		MAGIC	NPVLCC—GH/ NPVLCC-Magic
RDTE:$300M, $510M, $1300M	RDTE				
Total NPV LCC	$300.00	$7,889.26		$1,326.35	5.95
Dis=0.0; APUC=$17M	$510.00	$7,889.26		$1,536.35	5.14
	$1,300.00	$7,889.26		$2,326.35	3.39
Total NPV LCC	$300.00	$6,955.07		$1,204.64	5.77
Dis=0.025; APUC=$17M	$510.00	$6,955.07		$1,414.64	4.92
	$1,300.00	$6,955.07		$2,204.64	3.15
	$6,050	6955.07		$6,954.64	1.00
Total NPV LCC	$300.00	$6,183.77		$1,104.14	5.60
Dis=0.05; APUC=$17M	$510.00	$6,183.77		$1,314.14	4.71
	$1,300.00	$6,183.77		$2,104.14	2.94
Total NPV LCC	$300.00	$7,889.26		$1,237.07	6.38
Dis=0; APUC = $14M	$510.00	$7,889.26		$1,447.07	5.45
	$1,300.00	$7,889.26		$2,237.07	3.53
Dis=0.025; APUC = $14M	$300.00	$6,955.07		$1,125.37	6.18
	$510.00	$6,955.07		$1,335.37	5.21
	$1,300.00	$6,955.07		$2,125.37	3.27
	$6,170	$6,955.07		$6,995.37	0.99
Dis=0.05; APUC = $14M	$300.00	$6,183.77		$1,033.15	5.99
	$510.00	$6,183.77		$1,243.15	4.97
	$1,300.00	$6,183.77		$2,033.15	3.04
Total NPV LCC	$300.00	$7,889.26		$1,415.64	5.57
Dis=0; APUC = $20M	$510.00	$7,889.26		$1,625.64	4.85
	$1,300.00	$7,889.26		$2,415.64	3.27
Dis=0.025; APUC = $20M	$300.00	$6,955.07		$1,283.90	5.42
	$510.00	$6,955.07		$1,493.90	4.66
	$1,300.00	$6,955.07		$2,283.90	3.05
	$6,010	$6,955.07		$6,993.90	0.99
Dis=0.05; APUC = $20M	$300.00	$6,183.77		$1,175.14	5.26
	$510.00	$6,183.77		$1,385.14	4.46
	$1,300.00	$6,183.77		$2,175.14	2.84

Table 17. Return Ratios for MAGIC and Global Hawk for 500 nm range

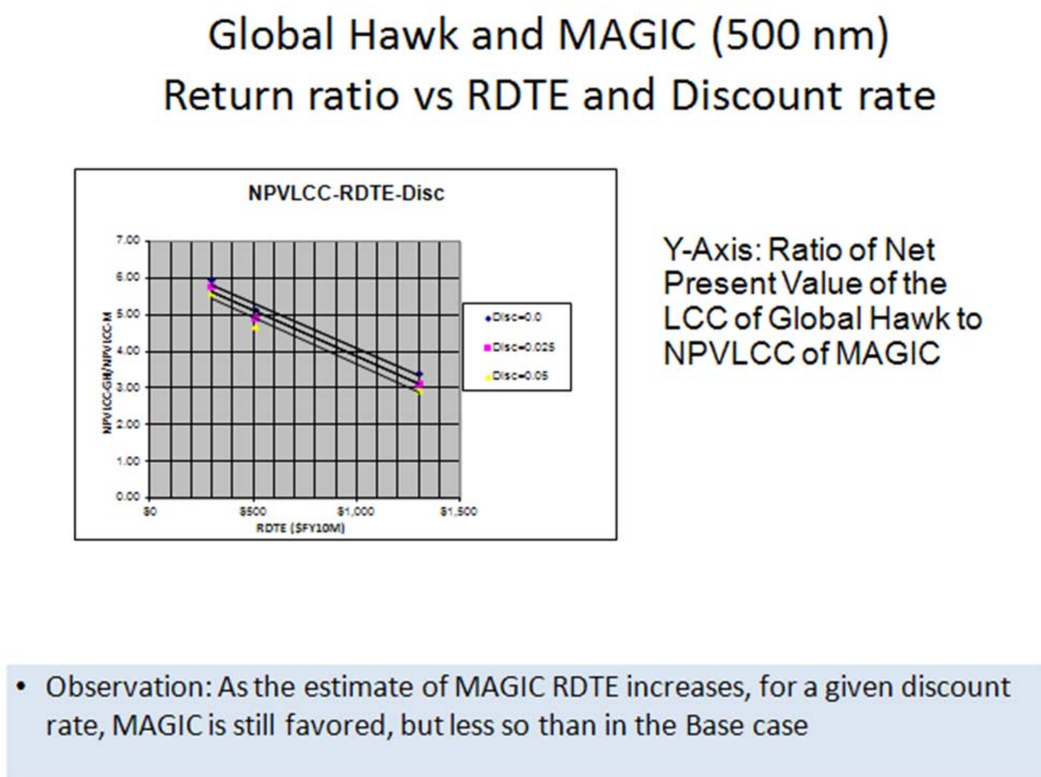
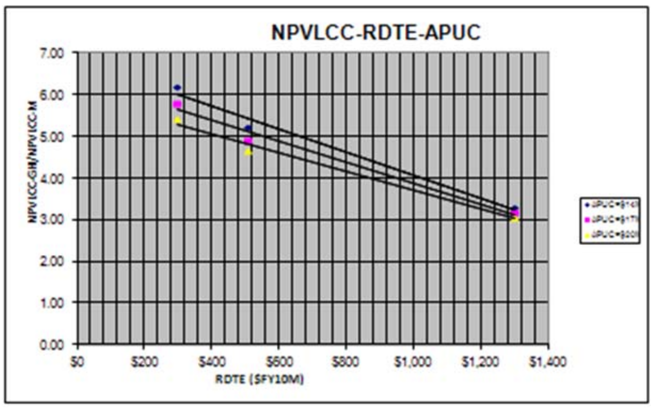


Figure 16. Design Trade Space for MAGIC and Global Hawk using RR vs. RDTE varying Discount factor for 500 nm range

Global Hawk and MAGIC (500 nm)
Return ratio vs RDTE and APUC

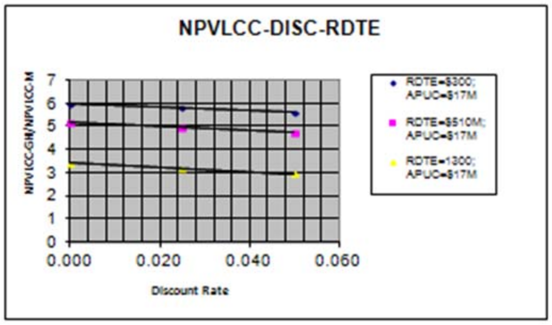


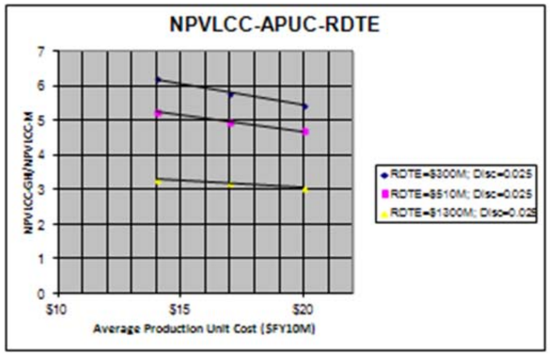
Observations:

- For a given RDTE, as MAGIC's APUC decreases, MAGIC is more favored.
- For a given APUC, as MAGIC's RDTE decreases, MAGIC is more favored

Figure 17. Design Trade Space for MAGIC and Global Hawk using RR vs. RDTE varying APUC for 500 nm range

Global Hawk and MAGIC
Return ratio vs Discount rate, RDTE and Average Production Unit Cost (APUC)





- Observations:
  - The return ratio decreases as discount rate increases ; MAGIC is less favored (Left Figure)
  - The return ratio decreases as APUC increases; MAJIC is less favored (Right Figure)

Design Trade Space for MAGIC and Global Hawk using RR vs. df varying RDT&E and RR vs. APUC varying RDTE for 500 nm

Return Ratio Magic-GHawk (2000 nm)

Sensitivity Analysis	$FY10M	$FY10M	$FY10M	
		GlobalHawk	MAGIC	NPVLCC-G/ NPVLCC-M
RDTE: $300M, $510M, $1300M	RDTE			GH/Mag
Total NPV LCC	$300.00	$9,862.00	$1,669.00	5.91
DIs=0.0; APUC=$17M	$510.00	$9,862.00	$1,879.00	5.25
	$1,300.00	$9,862.00	$2,669.00	3.70
	$8,490.00	$9,862.00	$9,859.00	1.00
Total NPV LCC	$300.00	$8,694.00	$1,506.00	5.77
DIs=0.025; APUC=$17M	$510.00	$8,694.00	$1,716.00	5.07
	$1,300.00	$8,694.00	$2,506.00	3.47
	$7,490.00	$8,694.00	$8,696.00	1.00
Total NPV LCC	$300.00	$7,730.00	$1,372.00	5.63
DIs=0.05; APUC=$17M	$510.00	$7,730.00	$1,582.00	4.89
	$1,300.00	$7,730.00	$2,372.00	3.26
	6657	$7,730.00	$7,729.00	1.00
Total NPV LCC	$300.00	$9,862.00	$1,549.00	6.37
DIs=0; APUC = $14M	$510.00	$9,862.00	$1,759.00	5.61
	$1,300.00	$9,862.00	$2,549.00	3.87
	8600	$9,862.00	$9,849.00	1.00
DIs=0.025; APUC = $14M	$300.00	$8,694.00	$1,401.00	6.21
	$510.00	$8,694.00	$1,611.00	5.40
	$1,300.00	$8,694.00	$2,401.00	3.62
	$7,590.00	$8,694.00	$8,691.00	1.00
DIs=0.05; APUC = $14M	$300.00	$7,730.00	$1,278.00	6.05
	$510.00	$7,730.00	$1,488.00	5.19
	$1,300.00	$7,730.00	$2,278.00	3.39
	6750	$7,730.00	$7,728.00	1.00
Total NPV LCC	$300.00	$9,862.00	$1,788.00	5.52
DIs=0; APUC = $20M	$510.00	$9,862.00	$1,998.00	4.94
	$1,300.00	$9,862.00	$2,788.00	3.54
	8370	$9,862.00	$9,858.00	1.00
DIs=0.025; APUC = $20M	$300.00	$8,694.00	$1,612.00	5.39
	$510.00	$8,694.00	$1,822.00	4.77
	$1,300.00	$8,694.00	$2,612.00	3.33
	$7,380.00	$8,694.00	$8,692.00	1.00
DIs=0.05; APUC = $20M	$300.00	$7,730.00	$1,467.00	5.27
	$510.00	$7,730.00	$1,677.00	4.61
	$1,300.00	$7,730.00	$2,467.00	3.13
	$6,560.00	$7,730.00	$7,727.00	1.00

Table 18. Return Ratios for MAGIC and Global Hawk for 2000 nm range

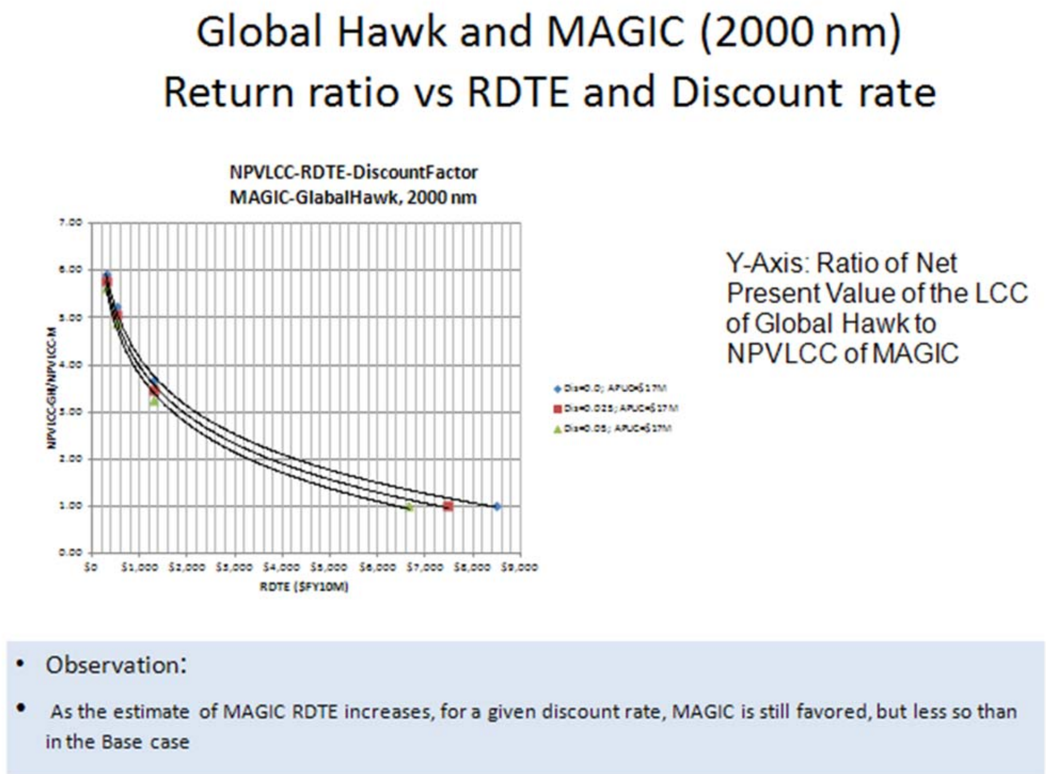


Figure 18. Design Trade Space for MAGIC and Global Hawk using RR vs. RDT&E varying df for 2000 nm range

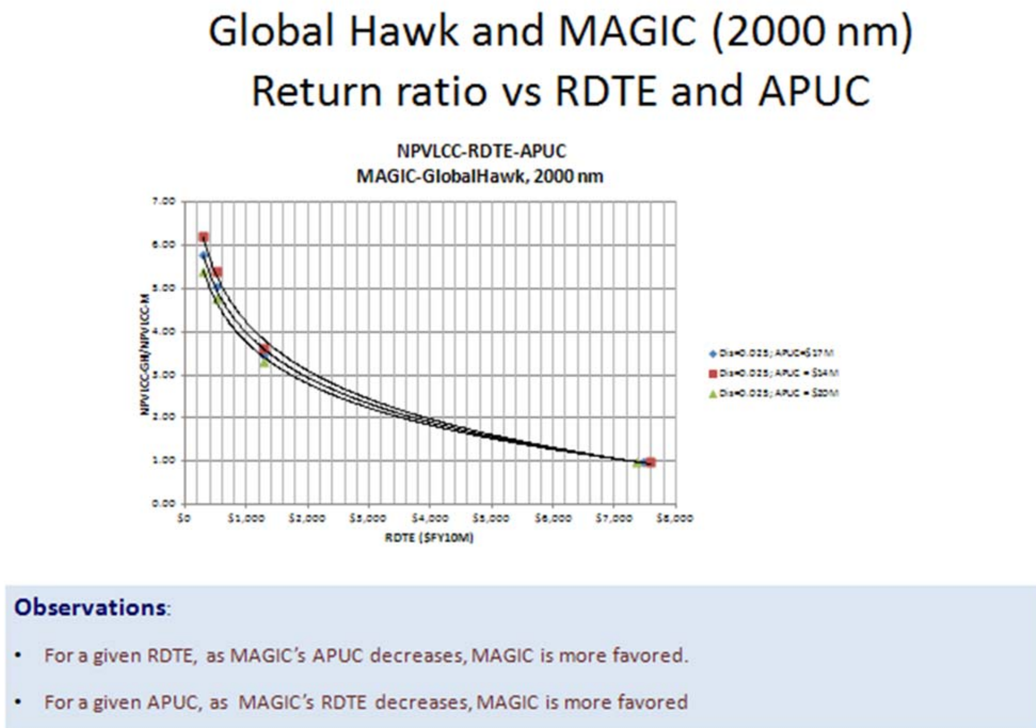


Figure 19. Design Trade Space for MAGIC and Global Hawk using RR vs. RDTE varying df for 2000 nm range

Return Ratio Magic-GHawk (3000 nm)

Sensitivity Analysis	$FY10M	$FY10M	$FY10M	
		GlobalHawk	MAGIC	NPVLCC-G/ NPVLCC-M
RDTE:$300M, $510M, $1300M	RDTE			GH/Mag
Total NPV LCC	$300.00	$21,696.00	$2,353.00	9.22
Dis=0.0; APUC=$17M	$510.00	$21,686.00	$2,563.00	8.46
	$1,300.00	$21,696.00	$3,353.00	6.47
	$19,640.00	$21,696.00	$21,693.00	1.00
Total NPV LCC	$300.00	$19,126.00	$2,109.00	9.07
Dis=0.025; APUC=$17M	$510.00	$19,126.00	$2,319.00	8.25
	$1,300.00	$19,126.00	$3,109.00	6.15
	$17,317.00	$19,126.00	$19,126.27	1.00
Total NPV LCC	$300.00	$17,005.00	$1,908.00	8.91
Dis=0.05; APUC=$17M	$510.00	$17,005.00	$2,118.00	8.03
	$1,300.00	$17,005.00	$2,908.00	5.85
	15400	$17,005.00	$17,008.00	1.00
Total NPV LCC	$300.00	$21,696.00	$2,174.00	9.98
Dis=0; APUC = $14M	$510.00	$21,696.00	$2,384.00	9.10
	$1,300.00	$21,696.00	$3,174.00	6.84
	19820	$21,696.00	$21,694.00	1.00
Dis=0.025; APUC = $14M	$300.00	$19,126.00	$1,951.00	9.80
	$510.00	$19,126.00	$2,161.00	8.85
	$1,300.00	$19,126.00	$2,951.00	6.48
	$17,475.00	$19,126.00	$19,125.70	1.00
Dis=0.05; APUC = $14M	$300.00	$17,005.00	$1,766.00	9.63
	$510.00	$17,005.00	$1,976.00	8.61
	$1,300.00	$17,005.00	$2,766.00	6.15
	15540	$17,005.00	$17,006.00	1.00
Total NPV LCC	$300.00	$21,696.00	$2,531.00	8.57
Dis=0; APUC = $20M	$510.00	$21,696.00	$2,742.00	7.91
	$1,300.00	$21,696.00	$3,531.00	6.14
	19460	$21,696.00	$21,691.00	1.00
Dis=0.025; APUC = $20M	$300.00	$19,126.00	$2,268.00	8.43
	$510.00	$19,126.00	$2,478.00	7.72
	$1,300.00	$19,126.00	$3,268.00	5.85
	$17,160.00	$19,126.00	$19,128.00	1.00
Dis=0.05; APUC = $20M	$300.00	$17,005.00	$2,050.00	8.30
	$510.00	$17,005.00	$2,260.00	7.52
	$1,300.00	$17,005.00	$3,050.00	5.58
	$15,260.00	$17,005.00	$17,010.00	1.00

Table 19. Return Ratios for MAGIC and Global Hawk for 3000 nm range

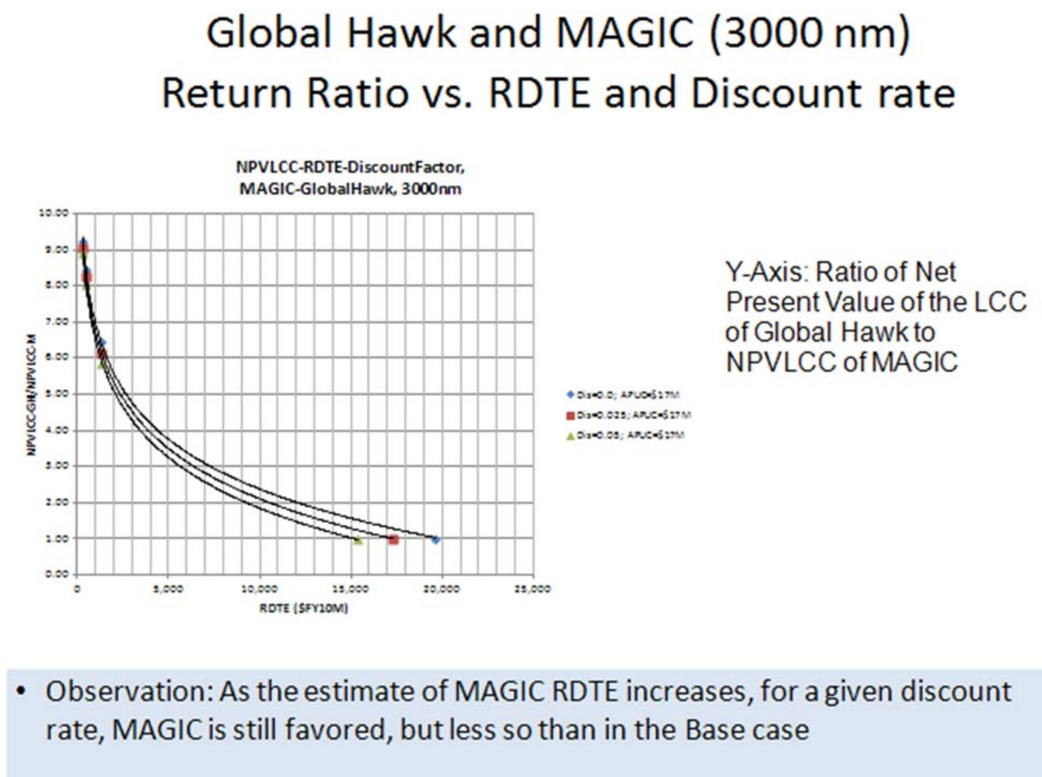


Figure 20. Design Trade Space for MAGIC and Global Hawk using RR vs. RDT&E varying df for 3000 nm range

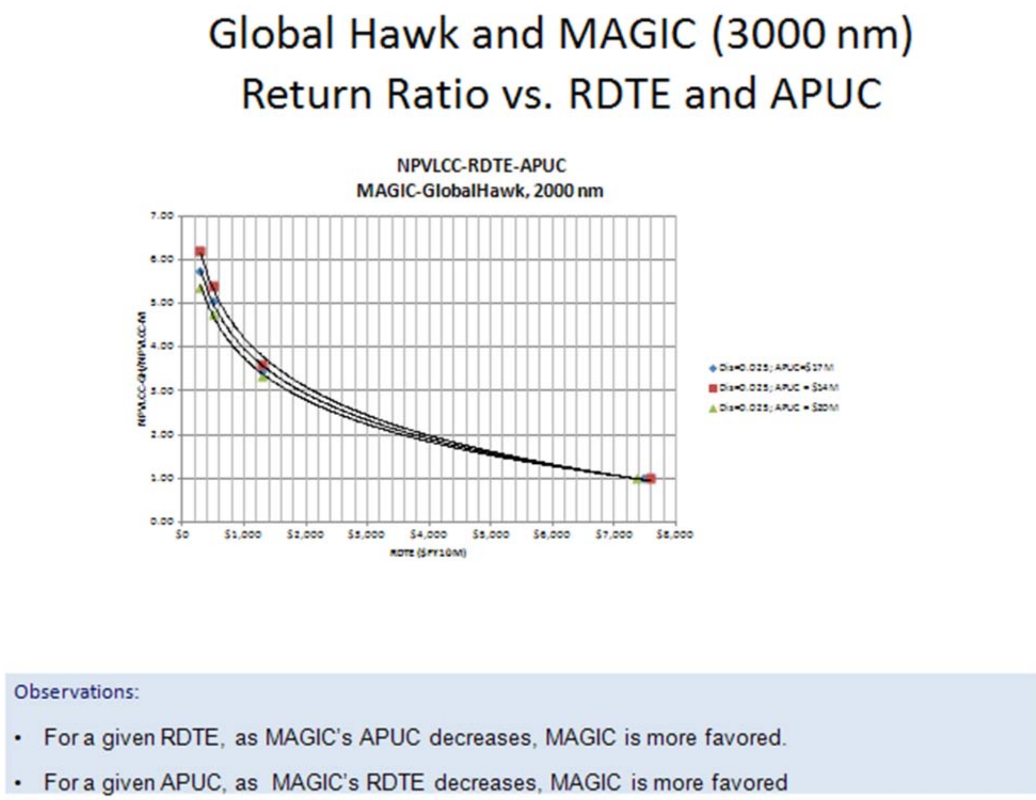


Figure 21. Design Trade Space for MAGIC and Global Hawk using RR vs. RDT&E varying APUC for 3000 nm range

APPENDIX C. ADDITIONAL RESULTS FOR MAGIC AND REAPER

This appendix presents additional tables and graphs for MAGIC and Reaper. The results and interpretations are similar to the results in the main chapters.

Return Ratio Magic-Reaper (500 nm)

Sensitivity Analysis	$FY10M	$FY10M		$FY10M	
		Reaper		MAGIC	NPVLCC-RpR / NPVLCC-Magic
RDTE:$300M, $510M, $1300M	RDTE				RpR/Mag
Total NPV LCC	$300.00	$1,862.11		$1,326.35	1.40
Dis=0.0; APUC=$17M	$510.00	$1,862.11		$1,536.35	1.21
	$1,300.00	$1,862.11		$2,326.35	0.80
Total NPV LCC	$300.00	$1,653.75		$1,204.64	1.37
Dis=0.025; APUC=$17M	$510.00	$1,653.75		$1,414.64	1.17
	$1,300.00	$1,653.75		$2,204.64	0.75
Total NPV LCC	$300.00	$1,481.72		$1,104.14	1.34
Dis=0.05; APUC=$17M	$510.00	$1,481.72		$1,314.14	1.13
	$1,300.00	$1,481.72		$2,104.14	0.70
Total NPV LCC	$300.00	$1,862.11		$1,237.07	1.51
Dis=0; APUC = $14M	$510.00	$1,862.11		$1,447.07	1.29
	$1,300.00	$1,862.11		$2,237.07	0.83
Dis=0.025; APUC = $14M	$300.00	$1,653.75		$1,125.37	1.47
	$510.00	$1,653.75		$1,335.37	1.24
	$1,300.00	$1,653.75		$2,125.37	0.78
Dis=0.05; APUC = $14M	$300.00	$1,481.72		$1,033.15	1.43
	$510.00	$1,481.72		$1,243.15	1.19
	$1,300.00	$1,481.72		$2,033.15	0.73
Total NPV LCC	$300.00	$1,862.11		$1,415.64	1.32
Dis=0; APUC = $20M	$510.00	$1,862.11		$1,625.64	1.15
	$1,300.00	$1,862.11		$2,415.64	0.77
Dis=0.025; APUC = $20M	$300.00	$1,653.75		$1,283.90	1.29
	$510.00	$1,653.75		$1,493.90	1.11
	$1,300.00	$1,653.75		$2,283.90	0.72
Dis=0.05; APUC = $20M	$300.00	$1,481.72		$1,175.14	1.26
	$510.00	$1,481.72		$1,385.14	1.07
	$1,300.00	$1,481.72		$2,175.14	0.68

Table 20. Return Ratios for MAGIC and Reaper for 500 nm range

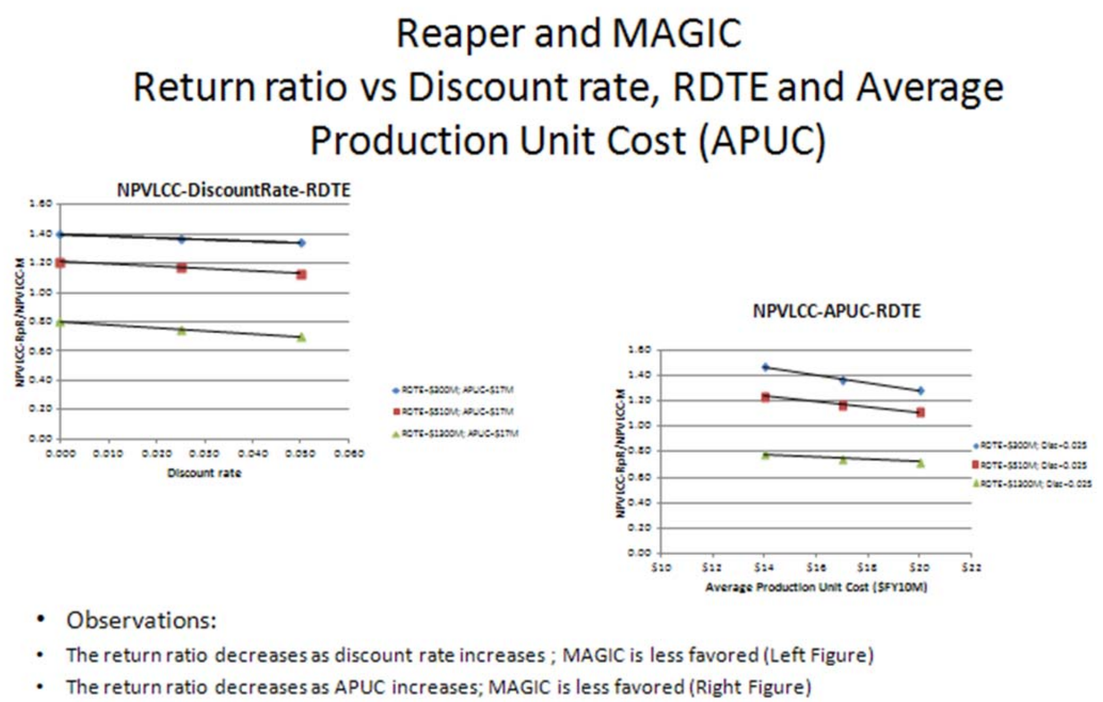


Figure 22. Design Trade Space for MAGIC and Reaper using RR vs. df varying RDT&E and RR vs. APUC varying RDTE for 500 nm range

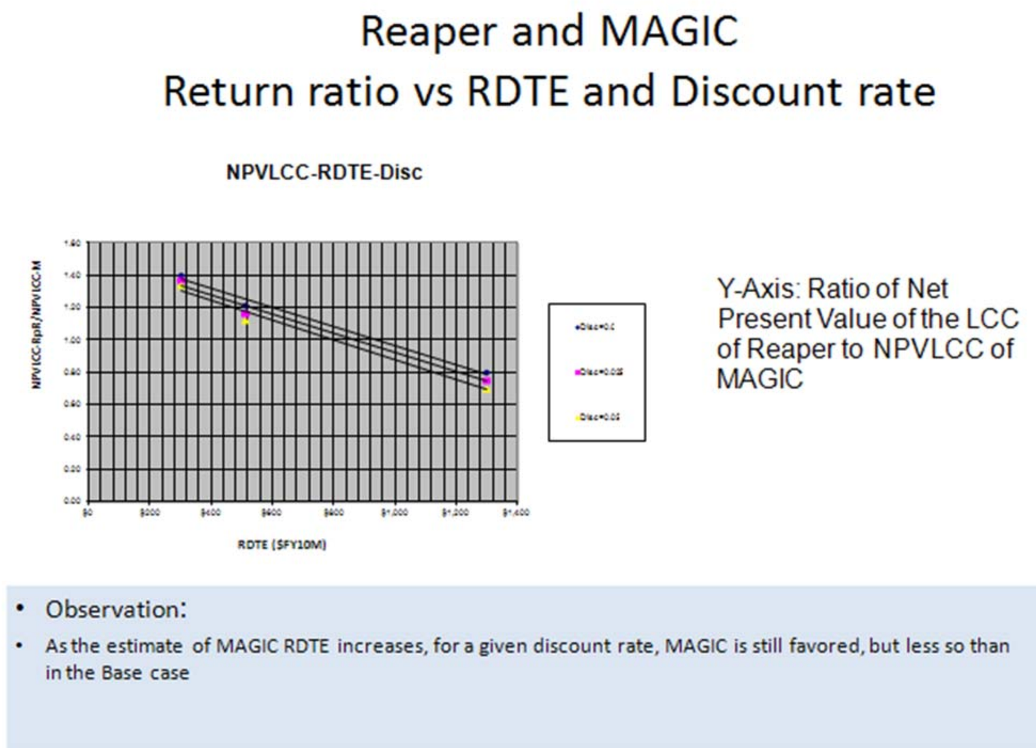


Figure 23. Design Trade Space for MAGIC and Reaper using RR vs. RDT&E varying Discount Rate for 500 nm range

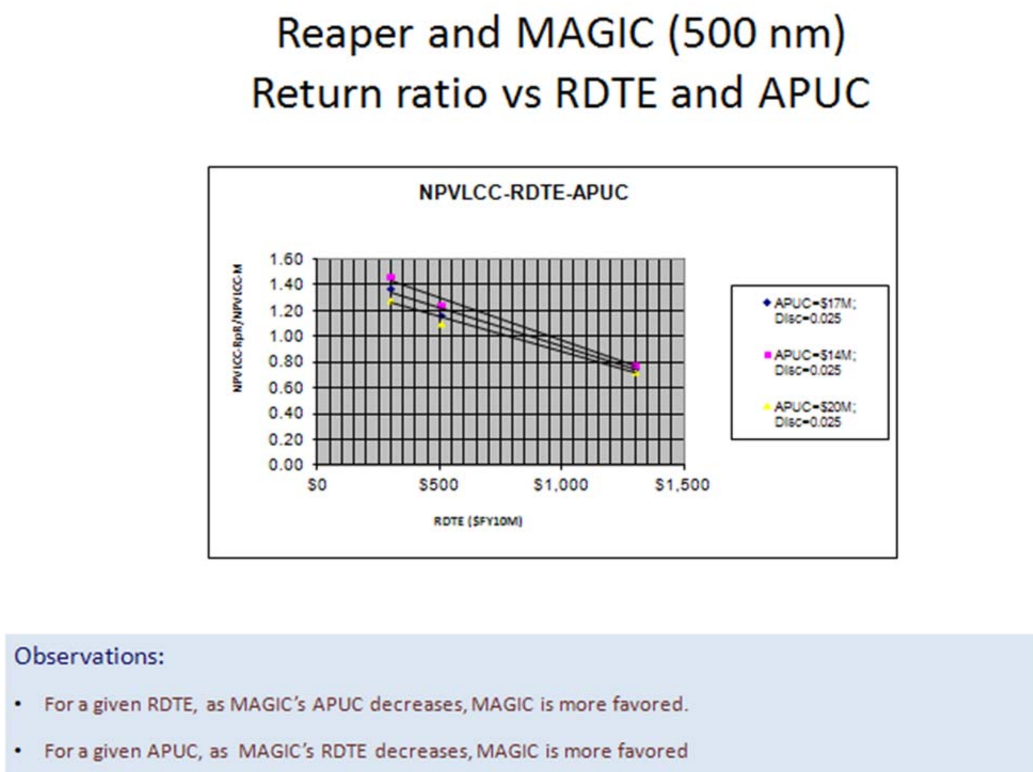


Figure 24. Design Trade Space using RR vs. RDT&E varying APUC for 500 nm range

Return Ratio Magic-Reaper (1000 nm)

Sensitivity Analysis	$FY10M	$FY10M	$FY10M	
		Reaper	MAGIC	NPVLCC-R/ NPVLCC-M
RDTE: $300M, $510M, $1300M	RDTE			RpR/Mag
Total NPV LCC	$300.00	$3,192.00	$1,326.35	2.41
Dis=0.0; APUC=$17M	$510.00	$3,192.00	$1,536.35	2.08
	$1,300.00	$3,192.00	$2,326.35	1.37
	$2,166.00	$3,192.00	$3,192.00	1.00
Total NPV LCC	$300.00	$2,835.00	$1,204.64	2.35
Dis=0.025; APUC=$17M	$510.00	$2,835.00	$1,414.64	2.00
	$1,300.00	$2,835.00	$2,204.64	1.29
	$1,930.00	$2,835.00	$2,834.64	1.00
Total NPV LCC	$300.00	$2,540.10	$1,104.14	2.30
Dis=0.05; APUC=$17M	$510.00	$2,540.10	$1,314.14	1.93
	$1,300.00	$2,540.10	$2,104.14	1.21
	1736	2540.1	$2,540.14	1.00
Total NPV LCC	$300.00	$3,192.00	$1,237.07	2.58
Dis=0; APUC = $14M	$510.00	$3,192.00	$1,447.07	2.21
	$1,300.00	$3,192.00	$2,237.07	1.43
	2255	3192	$3,192.00	1.00
Dis=0.025; APUC = $14M	$300.00	$2,835.00	$1,125.37	2.52
	$510.00	$2,835.00	$1,335.37	2.12
	$1,300.00	$2,835.00	$2,125.37	1.33
	$2,010.00	$2,835.00	$2,835.00	1.00
Dis=0.05; APUC = $14M	$300.00	$2,540.00	$1,033.15	2.46
	$510.00	$2,540.00	$1,243.15	2.04
	$1,300.00	$2,540.00	$2,033.15	1.25
	1800	2540	$2,533.00	1.00
Total NPV LCC	$300.00	$3,192.00	$1,415.64	2.25
Dis=0; APUC = $20M	$510.00	$3,192.00	$1,625.64	1.96
	$1,300.00	$3,192.00	$2,415.64	1.32
	2077	3192	$3,193.00	1.00
Dis=0.025; APUC = $20M	$300.00	$2,835.00	$1,283.90	2.21
	$510.00	$2,835.00	$1,493.90	1.90
	$1,300.00	$2,835.00	$2,283.90	1.24
	$1,850.00	$2,835.00	$2,834.00	1.00
Dis=0.05; APUC = $20M	$300.00	$2,540.00	$1,175.14	2.16
	$510.00	$2,540.00	$1,385.14	1.83
	$1,300.00	$2,540.00	$2,175.14	1.17
	$1,665.00	$2,540.00	$2,540.14	1.00

Table 21. Return Ratios for MAGIC vs Reaper for 1000 nm range

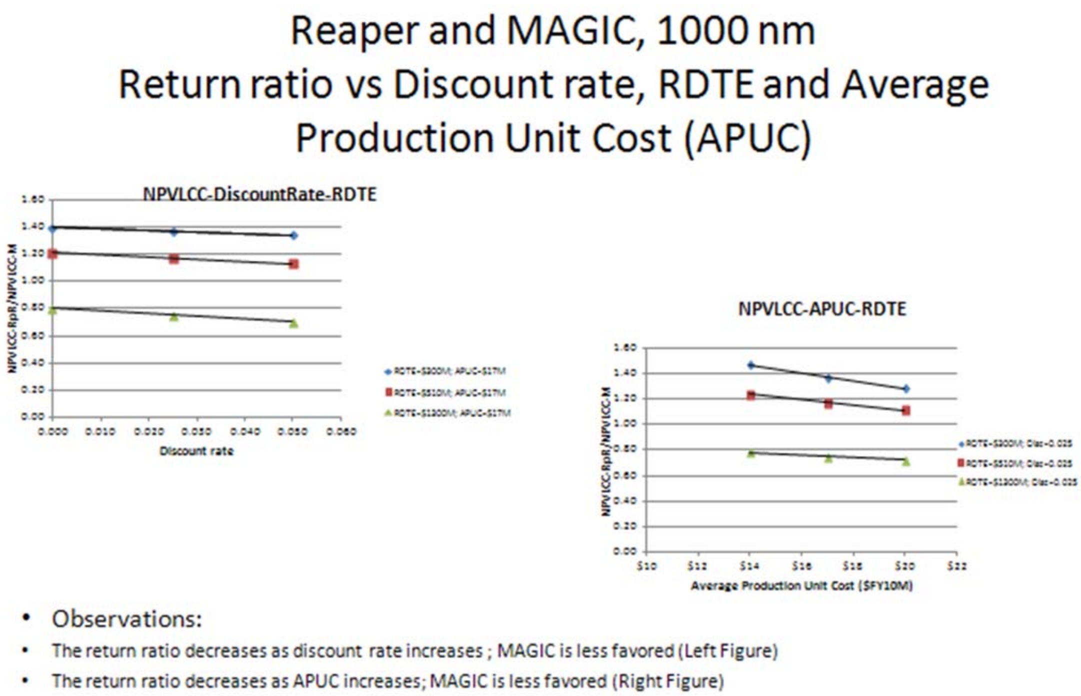


Figure 25. Design Trade Space for MAGIC vs Reaper using RR vs. Discount rate varying RDT&E and RR vs. APUC varying RDT&E for 1000 nm range

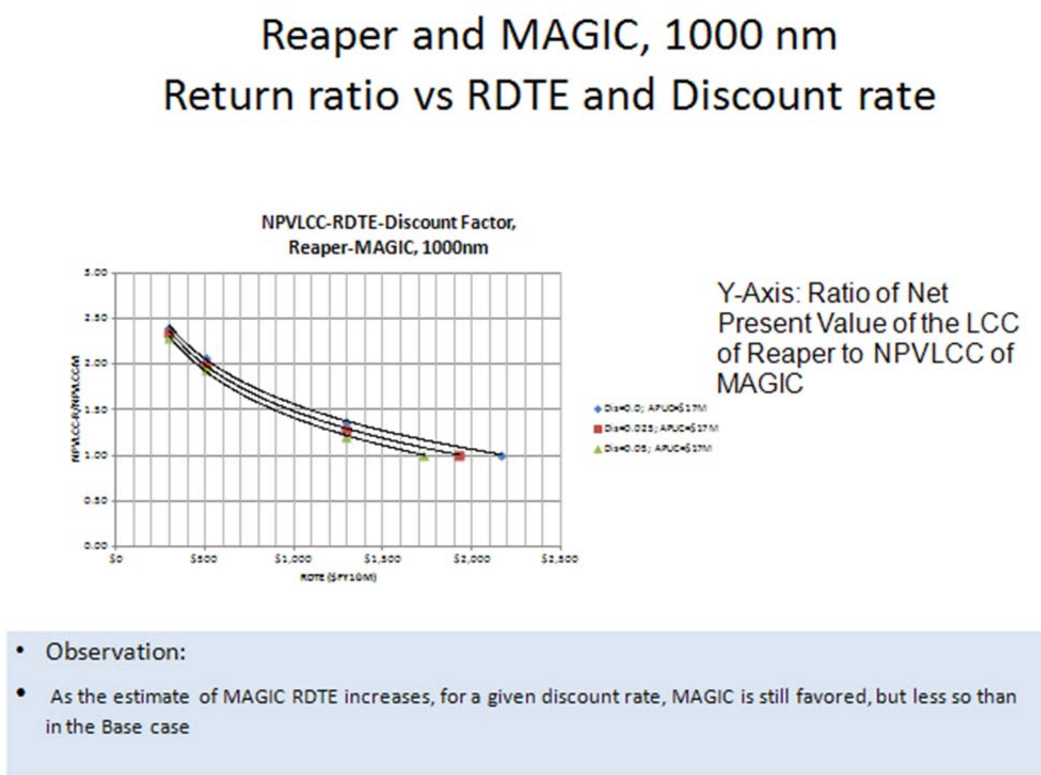


Figure 26. Design Trade Space for MAGIC and Reaper using RR vs. RDT&E varying Discount rate for 1000 nm range

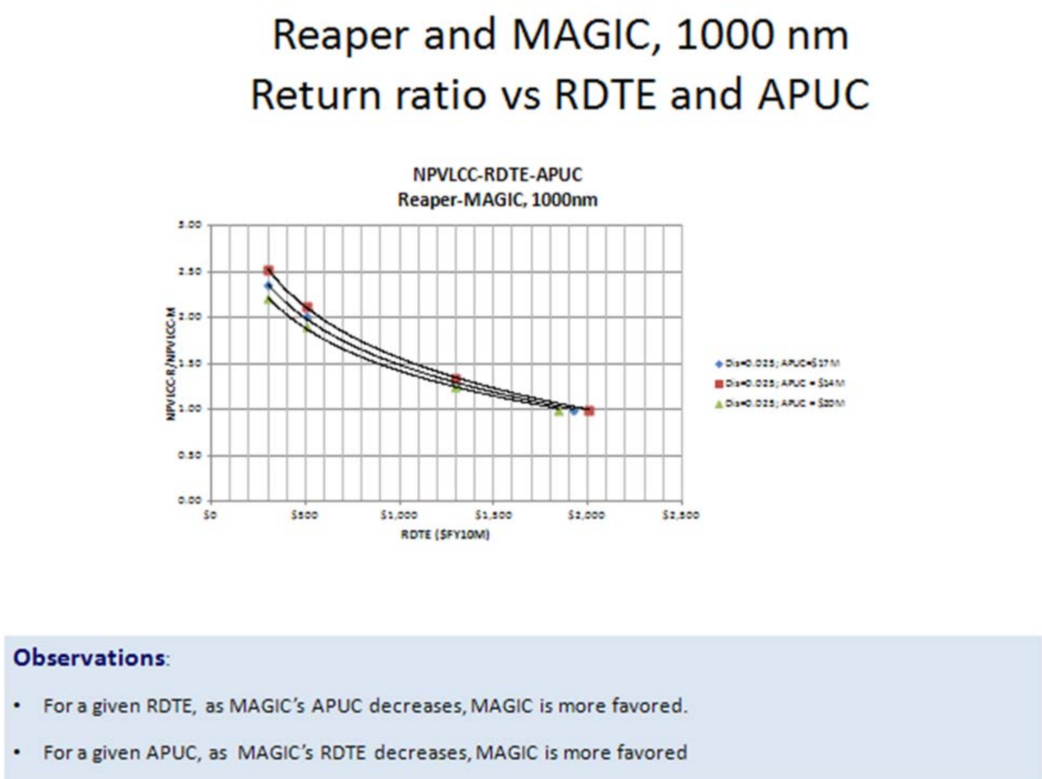


Figure 27. Design Trade Space for MAGIC and Reaper using RR vs. RDT&E varying APUC for 1000 nm range

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